AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

425.

(Vol. XXI.—October, 1889.)

FINAL REPORT OF THE COMMITTEE ON THE PROPER RELATION TO EACH OTHER OF THE SECTIONS OF RAILWAY WHEELS AND RAILS.

To the President and Members of the American Society of Civil Engineers:

Your Committee, to whom were referred the questions covered by the subjoined resolution,* has satisfaction in reporting that since the appearance of its Preliminary Report it has discovered by circulars of inquiry that a fair approach to unanimity of sentiment exists among engineers in regard to the questions involved. It now unanimously submits the following final report:†

* The Committee is acting under the following resolution offered at the Deer Park Convention, June 25, 1885:

"*Whereas*, The relation which the form of the head of a rail should bear to the section of a car-wheel tread and flange has recently been in dispute, it being asserted, on the one hand, that they should have as long a line of contact as possible, and, on the other hand, that such long contact would be dangerous and injurious; and,

"*Whereas*, The question raised by this diversity of view is of direct importance to the many members of this Society, as well as to the public interest, and hence is one which this Society may appropriately consider through Committee; therefore be it

"*Resolved*, That a Committee of five members of this Society be appointed by the President to consider and report to the Society on the proper relation to each other of the sections of rails and wheels; to what extent and at what points it is expedient that their sections should be such as to bring them normally in contact, and to what extent and at what points it is not expedient that they should be so in contact; and that the Committee be instructed to seek information from all those who are known to have given the subject attention."

This resolution was submitted to letter ballot and adopted by a general vote of the Society. Subsequently, by vote at the annual meeting, the President was authorized to add two additional members to such Committee. The Committee then sent out circulars of inquiry to all those deemed likely to be able to aid them by submitting definite records bearing on the question, and submitted a preliminary report giving in full all the valuable information thus gathered, with their preliminary conclusions based on a study thereof. (See Trans. Am. Soc. C. E., Vol. XIX, page 1.)

† At the Annual Convention, June 24th, 1889, this report was received, and the Committee discharged with the thanks of the Society for the very valuable work which they have done.

The Preliminary Report of the Committee was published in the Transactions of the Society for July, 1888. A copy of this report was sent to all members of the Society, and to about 250 others, railway officers and engineers not members of the Society, including all those known to the Committee as having shown interest in the subject in any way. Circulars of inquiry asking certain specific questions (reprinted in Appendix A) were sent out in the same manner to all persons in and out of the Society, some 500 in all, known or thought to be interested in the question. The responses have been numerous and valuable. Sixty-four responses, many of them very elaborate and complete, have been received from engineers, mechanical officers, rail manufacturers and others as specified in the subjoined list,* including a large majority of those whose views the Committee was most anxious to obtain. All the Eastern trunk lines and numerous other

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* The Committee have received discussions in response to their circular, most of them answering in full and giving reasons for their opinions, from the following persons, in addition to which a number of discussions were received not in answer to specific questions and hence not readily abstracted.

DECATUR AXTELL.....Receiver, Richmond and Alleghany R. R.
W. S. G. BAKER.....Prest., Baltimore Car Wheel Co.
OLIVER W. BARNES.....Ex-Chief Engineer, So. Penna. R. R., etc.
M. J. BECKER.....Chief Engineer, Pittsburgh, Cinc. and St. Louis Ry.
CHARLES BLACKWELL.....Engr. of Machinery, Georgia Central R. R.
J. BLICKENSDERFER .....Consulting Engineer, Union Pacific Ry.
VIRGIL G. BOGUE.....Chief Engineer, Union Pacific Ry.
J. M. BOON.....Supt. Motive Power, West Shore R. R.
M. F. BONZANO.....Supt., P. and N. Y. Div. Phila. and Reading R. R.
G. BOUSCAREN.....Consulting Engineer, Ex-Chief Engineer, Cincinnati So. Ry.
THOMAS J. BRERETON.....Supervisor, Penna. R. R.
WM. H. BROWN.....Chief Engineer, Penna. R. R.
R. E. BRIGGS.....Chief Engineer, Denver and Rio Grande Ry.
WM. BUCHANAN.....Supt. Motive Power, N. Y. C. and H. R. R. R.
M. BURPEE.....Chief Engineer, New Brunswick Ry.
EDWARD C. CARTER.....Prin. Asst. Engr., Chicago and N. W. Ry.
WILSON CROSBY.....Civil Engineer, Bangor, Me.
J. FOSTER CROWELL.....Civil Engineer, Ex-Engineer of Construction, Penna. R. R.
W. G. CURTIS.....Supt. Track, Southern Pacific Ry. (with other officers).
F. G. DARLINGTON.....Supt. Cinc. and Muskingum Valley R. R.
F. A. DELANO.....Chief of Bureau of Rail and Rail Joint Inspections, Tests and Records, Chicago, Burlington and Q. R. R.
M. M. DEFREES.....Engineer of Bridges and Buildings, Ohio, Ind'a and W. R. R.
P. H. DUDLEY.....Engineer of Tests, etc., N. Y. C. and H. R. R. R.
ROBERT FLETCHER.....Professor of Civil Engineering, Dartmouth College.
ROBERT FORSYTH .....Manager Union Works, Illinois Steel Co., Chicago.
WILLIAM FORSYTH.....Mechanical Engineer, Chicago, B. and Q. R. R.
GEO. W. GIBBS.....Mechanical Engineer, Chicago, M. and St. P. Ry.
G. B. HAZLEHURST.....Engineer of Bridges and Tests, Baltimore and Ohio R. R.
J. D. HAWKS..... .....Chief Engineer, Michigan Central R. R.
H. V. HINCKLEY.....Office Engineer, Atchison, Topeka and Santa Fé R. R.

great systems are represented in these responses or on this Committee. The discussions will make a large pamphlet, and they are accompanied by many drawings. It was impossible to do more than tabulate the specific responses without unduly delaying this report; but the discussions constitute such a valuable collection of practical information as to rails and wheels that your Committee recommends their publication in full.

Your Committee was surprised as well as gratified to find that, instead of developing the diversity of opinion which is the frequent result of such inquiries, and which the condition of present practice as to rail sections made especially probable, the responses show throughout the degree of agreement as to essentials above noted, amounting almost to unanimity in respect to the specific questions submitted; those, namely, concerning the form and general proportions of the head of

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R. HITCHCOCK.....Master Car Builder, Conn. River R. R.
WM. E. HOYT.....Chief Engineer, Rochester and Pittsburgh R. R.
M. G. HOWE.....Receiver, Houston, E. and W. Texas and Pacific Ry.
J. B. JOHNSON.....Professor of Civil Engineering, Washington University.
THOS. H. JOHNSON.....Prin. Asst. Engr., Pittsburgh, Cinc. and St. Louis Ry.
WM. R. JONES.....Gen. Supt., etc , Edgar Thompson Steel Works, Pittsburgh, Pa.
WALTER KATTÉ.....Chief Engineer New York Central and H. R. R. R.
LEWIS KINGMAN.....Asst. Engr. Atchison, Topeka and Santa Fé R. R.
O. H. LANDRETH.....Professor of Civil Engineering, Vanderbilt University.
L. F. LOREE.....Engr. of Maint. of Way, Chicago, St. L. and Pittsburgh Ry.
A. P. MAN, JR.....Gen. Manager, Silver Springs, Ocala and Gulf R. R.
HUNTER MCDONALD.....Engineer in Charge, Nashv., Chatta. and St. L. Ry.
MANSFIELD MERRIMAN.....Professor of Civil Engineering, Lehigh University.
JAS. A. MILLHOLLAND.....Gen. Manager, George's Creek and Cumberland R. R.
S. F. MORRIS.....Div. Engr., New Croton Aqueduct, New York.
JOHN NEWELL.....President and Gen. Man., Lake Shore and M. S. Ry.
H. W. D. OTIS.....Gen. Roadmaster, N. Y. C. and H. R. R. R.
E. PONTZEN.....Civil and Consulting Engineer, Paris, France.
EDWARD W. PENFIELD.....Eng. in charge Rail Records, C., B. and Q. R. R.
THOS. PROSSER & SONS.....Steel Tire Manufacturers, representing Krupp Works.
J. T. RICHARDS.....Asst Chief Engineer, Pennsylvania R. R.
A. A. ROBINSON.....Vice-Prest. and Chief Engr., Atch., T. and S. F. Ry.
S. W. ROBINSON.....Professor Mechanical Engineering Ohio State University.
C. P. SANDBERG.....Rail Expert and Inspector, London, England.
WM. F. SEARLES.....Consulting Engineer, Cleveland, O.
R. I. SLOAN.....Chief Engineer, Manhattan (Elevated) Ry.
J. P. SNOW.....Civil Engineer, Woonsocket, R. I.
W. W. SNOW.....Prest and Gen. Man., Ramapo Wheel Works.
WATERMAN STONE.....Engr. and Supt., Providence, Warren and Bristol R. R., Providence, R. I.
A. J. SWIFT.....Chief Engr. R. R. Dept., Delaware and Hudson Canal Co.
G. H. THOMSON.....Bridge Engineer, N. Y. C. and H. R. R. R.
THEODORE VOORHEES.....As t. Gen. Supt., N. Y. C. and H. R. R. R.
H. D. WHITCOMB.....Chief Engr., Richmond and Alleghany Valley R. R.
W. HOWARD WHITE.....Ex-Asst. Chief Engr., C. B. and Q. R. R.
DON J. WHITTEMORE.....Chief Engineer, Chicago, Milwaukee and St. Paul Ry.

rails. This result has greatly encouraged your Committee in unanimously recommending, as it now does, the following details as standards for practice.

First.—YOUR COMMITTEE RECOMMENDS A TWELVE-INCH TOP RADIUS AS A STANDARD FOR RAIL-SECTIONS OF ALL WEIGHTS.

The discussions upon this question show so far as they answer it specifically:

In favor of 12-inch, "10 to 14 inches," etc.	36
[Axtell, Barnes, Becker, Bogue, Bonzano, Bouscaren, Brereton, Brown, Briggs, Crowell, Delano, Dudley, Forsyth (William), Gibbs, Hawks, Hinckley, Hitchcock. Hoyt, Johnson (T. H.), Jones, Katté, Kingman, Landreth, Loree, Man, McDonald, Merriman, Millholland, Newell, Penfield, Robinson (A. A.), Snow (J. P.), Stone, Swift, Thomson, Whitcomb.]	
In favor of 12-inch or less	3
[Forsyth (Robert), Richards, Sandberg.]	
In favor of 12-inch or somewhat more	5
[Burpee, Carter, Fletcher, Pontzen, White.]	
In favor of 12-inch by implication [Curtis]	1
Total favoring about 12-inch top radius	45
In favor of flat top	7
[Blackwell, Darlington, Defrees, Hazlehurst, Morris, Searles, Whittemore.]	
Prefers flat top [Howe]	1
Prefers 20 to 30 inches (Robinson, S. W.)	1
Total favoring flat top	9

The prevailing sentiment, which your Committee shares, appears to be that the end sought in the suggestion of an entirely flat top between the rounded corners, viz., a wider bearing for the wheel-tread, is a desirable one; but that it is and will be better secured in practice by using a slight curve for the top of the section, instead of a straight line. The evidence is that an entirely flat top is difficult, if not impossible, to roll properly; trials have resulted badly. Inevitable irregularities of track and the usual slight bends in the web, due to the rails lying on their sides when hot, would throw the bearing of the wheel-tread on one or the other corner instead of evenly across the top, causing early

flowage and rounding of section. The standard wheel-tread (shown in Appendix A) is now slightly coned, a perfectly cylindrical tread having been first rejected. While few hold that the coning has a sensible influence on curve resistance, the belief is general that coning does have a sensible steadying effect to diminish oscillation, and it is questionable if it would be wise to wholly dispense with it. Were the tread originally perfectly cylindrical, with an even bearing for the whole width of rail head, the necessary gauge play alone would tend to wear it hollow. Under existing conditions wheel treads wear slightly hollow, corresponding to about a 12-inch radius, very early in their lives. As a consequence, nearly all rails now wear down to a curved top on the outside as well as the inside of the head. (See Fig. 7 of the Committee's Preliminary Report, reproduced in Appendix A.) Were flat rails and cylindrical wheels universal on any one line, and were they thus made free from all tendency to wear to a curve, the constant interchange of cars would bring hollow treads on flat rails and straight treads on round-top rails. With the top curve the load is sustained centrally and transmitted directly downward through the web. Without it, one or the other corner will sustain the load in practice, and neither long in succession, causing a tendency to split off the side of the head if the metal be in any way defective. Most wheels being worn slightly hollow, the bearing is in practice now tolerably wide.

For these and other reasons, your Committee is entirely clear that the attempt to introduce a perfectly flat top is inexpedient.

Second.—YOUR COMMITTEE RECOMMENDS A BROAD HEAD RELATIVELY TO DEPTH FOR SECTIONS OF ALL WEIGHTS, taking care not to go too far in either dimension, especially in very large or very small sections, or to endanger the flange cutting into the joint.

The discussions upon this question show, so far as they categorically answer it (the Committee's question having been framed with reference to the proportions of the Michigan Central section, Fig. 1, Appendix A):

Unconditionally in favor of about that proportion..... 36

[Axtell, Barnes, Becker, Blackwell, Bonzano, Bouscaren, Crowell, Dudley, Fletcher, Forsyth (Robert), Gibbs, Hazlehurst, Hinckley, Hitchcock, Hoyt, Howe, (M. G.), Johnson, (T. H.), Jones, Katté, Kingman, Landreth, Loree, Man, McDonald, Merriman, Morris, Newell, Pontzen, Richards, Robinson (A. A.), Sandberg, Searles, Snow (J. P.), Swift, Whitcomb, White.]

Want head still wider in proportion..... 5
[Delano, Forsyth (William), Hawks, Penfield, Thomson.]
Wants head slightly narrower [Carter]..... 1
Approves for generally light alignment [Millholland]..... 1
Approves by implication [Curtis]..... 1
Total approving above recommendation..... 44
Disapproving [Brereton, Brown, Crosby, Robinson (S. W.)]. 4
Non-committal or doubtful answers.....2
[Bogue, Stone.]

Your Committee is much impressed with the weight of evidence and opinion tending to show that, in the effort to secure three ends in themselves desirable and proper, too little attention has been paid to metallurgical laws and processes of manufacture in designing rail sections. The tendency has been strong:

A.—To secure a broad bearing on the tie, by widening the base. At the same time:

B.—To save metal, by making the base thinner, and also the web; while:

C.—To increase tonnage life, additional metal has been placed on the top of the rail head. These ends, as stated, are in themselves good, but the result of seeking to attain them in this way is a great disproportion of mass in the different parts of the section; and this in turn requires that, in order to have the thinner portions of the section sufficiently plastic for the finishing passes through the rolls, the head must be so hot when it leaves the rolls as to be almost semi-fluid; and so the rolls do little of that effective compressive work which unquestionably is essential for properly consolidating and toughening either wrought-iron or steel. This unequal temperature after leaving the rolls also makes it much more difficut to insure that the rails shall be straight when cool, and hence results in more "gagging." As there exists also a constant and injurious tendency to roll even the thinner parts tolerably hot, in order to quicken the process, save making seconds, and reduce the number of passes, it will be seen how probable it is that the heads of many rails have been leaving the rolls in but little better molecular condition than when they entered them.

In European practice no such extreme conditions prevail. The double-headed or "bull-head" sections are nearly symmetrical about

their horizontal axis. Even in respect to the increasing proportion of flat-base American sections used in European practice, the tendency is to use narrower and thicker bases and thicker webs than have of late prevailed here. It seems probable that European practice has been in this respect more nearly correct than ours, and that our manufacturers have been at times suspected unjustly of using inferior metal and processes, when the real fault lay in the harder problem given them to solve, because of the form of the section. Your Committee knows of rails which chemical analysis and subsequent working under the hammer showed to be rolled from excellent metal, yet which showed a coarse, uneven fracture when broken, and proved almost worthless in service. An important contributing cause to the badness of many such rails may be insufficient allowance for the fact that hot metal, like cold, requires a certain time to flow, if its texture is to remain homogeneous; in other words, that the process of rolling must not be too fast; and your Committee does not regard a relatively wide head as in itself a cure-all, nor does it forget that many rails of quite unsymmetrical form have rendered good service; but it thinks it probable that better wearing qualities would be obtained by nearer approach to equality in mass and form of the base and head, while a relatively wide head also increases the top bearing surface.

Third.—YOUR COMMITTEE RECOMMENDS A ONE-FOURTH ($\frac{1}{4}$) INCH CORNER RADIUS, AS A STANDARD FOR SECTIONS OF ALL WEIGHTS.

The discussions on this question show, so far as they categorically answer it:

Explicitly in favor of $\frac{1}{4}$-inch radius	37
[Axtell, Barnes, Blackwell, Bonzano, Bouscaren, Brereton, Brown, Briggs, Burpee, Carter, Crosby, Crowell, Darlington, Defrees, Dudley, Fletcher, Forsyth (Robert), Forsyth (William), Gibbs, Hazlehurst, Hawks, Hitchcock, Hoyt, Johnson (T. H.), Katté, Landreth, Loree, Man, McDonald, Merriman, Morris, Penfield, Pontzen, Richards, Searles, Whitcomb, White.]	
In favor of $\frac{1}{4}$ to $\frac{5}{16}$-inch	3
[Becker, Thomson, Whittemore.]	
Prefers $\frac{5}{16}$-inch. [Delano, Robinson (S. W.), Snow (J. P.)]	3
Prefers by implication (sends section). [Newell]	1
In favor of $\frac{3}{8}$-inch	5
[Bogue, Hinckley,* Kingman,* Robinson (A. A.),* Howe.]	
Total favoring short corner radius	49
Explicitly in favor of $\frac{3}{8}$-inch radius or disapproving $\frac{1}{4}$-inch	5
[Baker, Millholland, Sandberg, Stone, Swift.]	

* Conditional upon fillet radius being the same.

Your Committee did not expect such unanimity in favor of a short corner radius. It can only say that it has especially endeavored, in every way, to secure discussions from those supposed to favor a long corner radius corresponding to the now standard $\frac{5}{8}$-inch wheel fillet. Only one such discussion has been offered; that of Mr. Millholland. The arguments on this question were given at length in the Committee's Preliminary Report, and the preliminary conclusions announced therein have been endorsed, as shown in Appendix A.

Fourth.—YOUR COMMITTEE RECOMMENDS A ONE-SIXTEENTH ($\frac{1}{16}$) INCH LOWER CORNER RADIUS FOR THE HEAD, AS A STANDARD FOR SECTIONS OF ALL WEIGHTS.

The discussions on this question show, so far as they categorically answer it:

Favor a very small radius (question was asked as to a $\frac{3}{32}$-inch radius; see Fig. 1, Appendix A)..... 31

[Barnes, Becker, Bouscaren, Brown, Briggs, Burpee, Carter, Crosby, Curtis, Darlington, Dudley, Hazlehurst, Hawks, Hitchcock, Hoyt, Howe, Johnson (T. H.), Jones, Katté, Loree, Man, McDonald, Milholland, Morris, Pontzen, Sandberg, Searles, Snow (J. P.), Swift, Whitcomb, White.]

Favor still smaller radius ($\frac{1}{16}$-inch)... 5

[Hinckley, Kingman, Newell, Robinson(A. A.), Thomson.]——

Total favoring $\frac{3}{32}$-inch or less..... 36

Opposed to so short a radius..... 7

[Blackwell, Bonzano, Brereton, Forsyth (Robert), Landreth, Robinson, S. W., Stone.]

"Possibly too small" [Bogue, Delano]..... 2

"Unimportant" [Axtell, Crowell,]..... 2

Non-committal..... 4

[Blickensderfer, Forsyth (William), Penfield, Richards.]

The purpose of the very short radius is, of course, to secure as much bearing as possible for the fish-plate, but your Committee is unable to see that it can do any harm even if no fish-plate be used. The evidence of the discussions from the rail-makers is, that there is no difficulty in rolling the section, even if the corner be a point, as some of the sections submitted have it. The specific section on which the question was based showed a $\frac{3}{32}$-inch radius, and it is impossible to say if as many would have approved it had it been $\frac{1}{16}$ nch instead; but from the general tenor of the discussions, your Committee feels satisfied that

they will do so now, and the principle of the short corner being approved, the Committee felt that it should recommend as short a one as was clearly practicable.

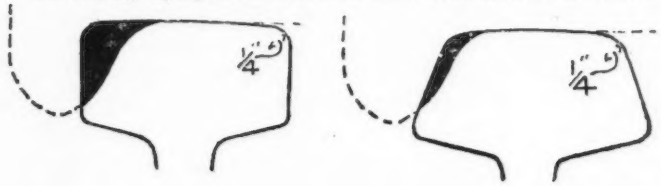
Fifth.—YOUR COMMITTEE RECOMMENDS THAT, STARTING FROM A SUFFICIENT BASE WIDTH OF HEAD TO GIVE AMPLE BEARING FOR THE JOINT, OR TO CONFORM TO RECOMMENDATION No. 1, THE SIDES BE CARRIED UP VERTICAL, AS A STANDARD FOR SECTIONS OF ALL WEIGHTS.

The discussions on this question, so far as they categorically answer it, show:

Explicity in favor of vertical sides	40
[Axtell, Barnes, Becker, Blackwell, Bogue, Bonzano, Bouscaren, Briggs, Burpee, Carter, Crosby, Crowell, Curtis, Darlington, Delano, Defrees, Fletcher, Forsyth (Robert), Forsyth (William), Gibbs, Hazlehurst, Hawks, Hinckley, Hitchcock, Hoyt, Johnson (T. H.), Kingman, Landreth, Loree, Man, McDonald, Merriman, Morris, Penfield, Pontzen, A. A. Robinson, Sandberg, Searles, Stone, Whitcomb.]	
In favor of vertical sides or nearly so [Richards]	1
" " " or an inward flare [Snow (J. P.)]	1
" " " or an outward flare [Howe, Katté]	2
" " " on tangents, slight incline for curves [Jones]	1
Total favoring in substance vertical sides	45
Opposed to vertical sides	9
[Brown, Dudley, Millholland, Swift, White; and wanting slight flare, 3 to 4 degrees: Brereton, Newell, Robinson (S. W.), and Thomson.]	

Starting from a proper base width, which appears the proper point to start from, and carrying the side up vertical instead of inclining inward, in the first place increases the top bearing surface, and in the second place increases the life of the rail by a trifling addition to the weight of the section, near the upper corner, where the metal is most useful and long-lived.

The accompanying cut shows in black the relative areas to be worn



away before the flange is bedded in the rail to the depth of one inch and hence approximately the relative tonnage life on the outside of curves; because, after the flange is once bedded in the rail to this depth, wear goes on at such an accelerated rate that the subsequent life of the rail, of whatever original section, amounts to little. By the vertical side, likewise, the difficulty about the gauging point is done away with, and the head is brought into a nearer approach to symmetry with the base.

The contrary practice starts with a given top width, and argues that by flaring out the sides there is more metal to be worn away before the rail becomes useless, while the bearing for the angle-bar is increased—which is true. But the added metal is put on chiefly at the bottom of the head, where it is least effective, and is cut away by the flange when it does reach it almost as fast as if it were lead. After a head has been designed with such an outward flare, by filling out the corner so as to restore the vertical side the life can be still further prolonged, as respects both flange wear and top wear, by metal very effectively disposed.

As respects any of the preceding recommendations, your Committee sees no reason why they will not give an equally favorable section for either curves or tangents, and either for angle-bar joints or for any form of base-support joint. An argument of some strength is advanced in favor of an inward flare for such joints, but your Committee sees no gain therefrom corresponding to the loss.

Sixth.—YOUR COMMITTEE ANNOUNCES AS FINAL CONCLUSIONS THE PRELIMINARY CONCLUSIONS AS TO THE GENERAL LAWS OF RAIL AND WHEEL WEAR INCLUDED IN ITS PRELIMINARY REPORT.

These conclusions, with a summary of what may be called the vote thereon, are appended hereunto in Appendix A. One or two verbal ambiguities, which seem to have caused misapprehension, are corrected; but beyond a few such verbal corrections the discussion has developed nothing which seems to indicate that any part of the Committee's Preliminary Report should be reconstructed.

Your Committee does not deem it proper to go beyond the above recommendations and attempt to elaborate details for standard sections complete. All that is included within the scope of its instructions it has now done. Anything beyond this must be done by a committee expressly appointed to recommend standard forms of rail sections, and

not merely to "consider the proper relations to each other of the sections of railway wheels and rails." But the fact that such unexpected unanimity of opinion has developed in respect to the proper form of the head of a rail section encourages the Committee to believe that a moderate amount of intelligent effort would secure the adherence of three-quarters, at least, of the engineers and railway mileage of the country to a set of standard sections elaborated after due inquiry and comparison of views.

Your Committee, having discharged the duty intrusted to it, now asks to be discharged.

Respectfully submitted,

H. STANLEY GOODWIN,
A. M. WELLINGTON,
SAMUEL REA,
GEORGE S. MORISON,
THOMAS RODD,
S. M. FELTON, JR.,
JAMES ARCHBALD,
} *Committee.*

APPENDIX A.

TO REPORT OF COMMITTEE ON FORM OF RAILS AND WHEELS, ETC.

The Committee sent out on April 20th, 1889, the following Circular of Inquiry, supplementary to another circular of date March 18th, which was was substantially identical except as explained in the body of this circular:

The Committee desire to supplement their last circular, which showed only one section (Fig. 1 herewith), by submitting with it two other sections, the three together being typical of all the varieties of practice which exist. You will greatly aid the Committee in the work of preparing a final report (especially if you have not yet answered the first circular), by answering briefly the following questions in regard to each of these sections. The preliminary report of the Committee, giving all the facts which they could collect, and the preliminary conclusions which the facts seemed to warrant, was published in the Transactions of this Society for July, 1888.

Please state if you approve or not the following features of the rail section shown in Fig. 1 (a lately adopted standard of the Michigan Central Railway)?

A. The ½-inch corner radius?
B. The 12-inch top radius?
C The vertical sides?
D. The very small lower corner radius?
E. The broad head relatively to depth?

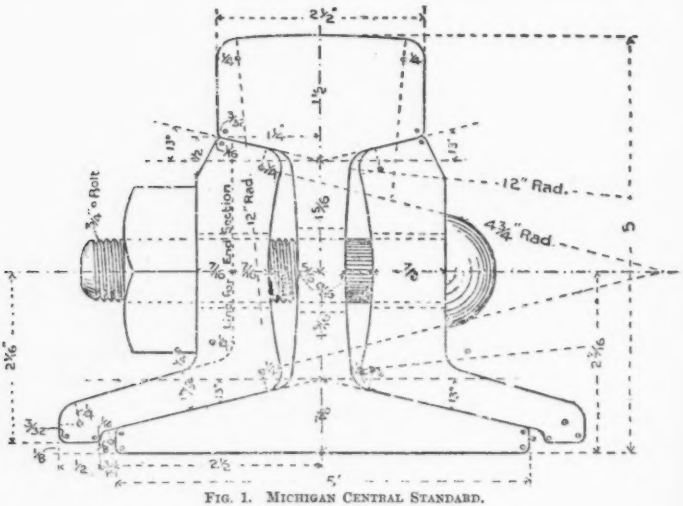


FIG. 1. MICHIGAN CENTRAL STANDARD.

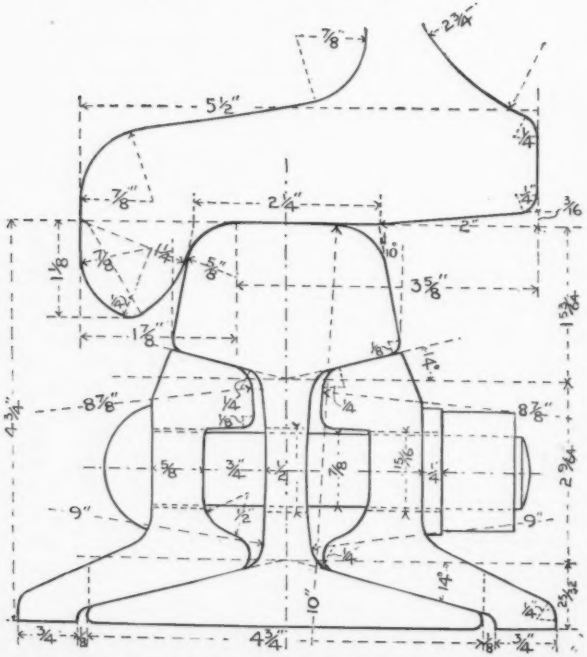


FIG. 2. LEHIGH VALLEY STANDARD.

Do you approve or not the following features of the rail section shown in Fig. 2 (the standard of the Lehigh Valley Raiload)?

A. The ⅜-inch corner radius, identical with a similar fillet radius for the inner corner of the flange?

B. The 10-inch top radius?

C. The decided flare of the sides?

D. The high and large head relatively to base?

Do you approve or not the following features of the rail section shown in Fig. 3 (the standard of the George's Creek and Cumberland Railroad)?

A. The corner radius identical with fillet radius of wheel?

B. The extension of the identical form of rail and wheel to afford bearing contact over the entire side of the rail and inside of flange, instead of over a part only?

C. The general form of the head?

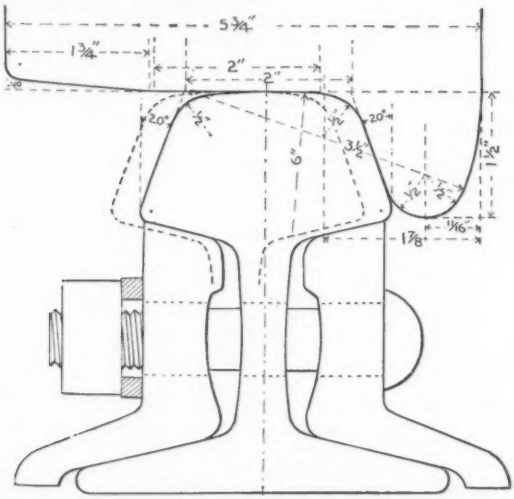


FIG. 3. GEORGE'S CREEK AND CUMBERLAND STANDARD.

Those who have not answered the previous circular of March 18th, are again asked to refer to the preliminary report of the Committee and answer the following questions in regard to it. The Committee cannot properly prepare a final report without a full expression of the views of those who are interested in this important question.

[The parts of the Preliminary Report referred to in the questions below are reprinted in this Appendix in connection with the vote.]

(1) Do you consider that the evidence submitted in the Committee's report, published in the Transactions of the Society for July, 1888, together with your own experience and observations, warrants accepting as final conclusions the preliminary conclusions as to causes of sharp flanges outlined at the foot of page 28? If not, please state your objections.

(2) Do you consider, on the same basis of fact and personal experience, that the preliminary conclusion as to rail-wear stated near the bottom of page 35, "that the rate of rail-wear grows very materially greater as the rail corner is rounded off to fit the fillet of the flange," may properly be accepted as a final conclusion? If not, please state your reasons.

(3) Do you consider that the engravings on page 38-9, with your own observations and experience, warrant the conclusion that worn rails in service take a top radius of about 12 inches, seldom much less or more, and a corner radius of about ½ inch, or somewhat more? If not, please state your own conclusions.

(4) Do you regard as warranted by the evidence the preliminary conclusions stated in the two paragraphs at the bottom of page 44? If not, why not?

(5) Do you regard as warranted the preliminary conclusions as to fillet radius, on page 45, at the end of the report?

(6) Mr. Don J. Whittemore, Past President Am. Soc. C. E., Chief Engineer of the Chicago, Milwaukee and St. Paul Railway, in a paper,* of which advance copies have been published by the Society, objects to any top curve at all, and proposes an entirely flat top between proper corner curves. Do you deem this likely to be effective in reducing rail-wear, and advise recommending an entirely flat top?

The responses to the questions asked as to the Michigan Central section, Fig. 1, are summarized in the body of this report. To the question as to the Lehigh Valley section, Fig. 2, the responses capable of summary were:

Disapprove unconditionally	22
[Axtell, Barnes, Blackwell, Bonzano, Bouscaren, Brereton, Burpee, Carter, Darlington, Delano, Fletcher, Gibbs, Hazlehurst, Hitchcock, Hoyt, Johnson (T. H.), Landreth, Loree, Merriman, Searles, Snow (J. P.), Stone.]	
Disapprove by implication (answered first circular, in which this question was not specifically asked, in favor of the main features of the Michigan Central section)	20
[Becker, Brown, Briggs, Crosby, Curtis, Defrees, Dudley, Forsyth (William), Hawks, Howe (M. G.), Jones, Katté, Man, McDonald, Morris, Newell, Penfield, Pontzen, Richards, Whitcomb.]	
Disapproves, but like high head [Crowell]	1
" " 10-inch top radius [Forsyth (Robert), Sandberg, Richards]	3
Disapproves, but likes the flare [White]	1
Total disapproving	47
Total approving [Baker, Millholland]	2
Non-committal [Hinckley, Kingman, Robinson (A. A.), Swift]	4
[Messrs. Hinckley, Kingman and Robinson (A. A.) are, by implication, disposed to favor Fig. 1 rather than Fig. 2, but do not so respond categorically.]	

* Transactions Am. Soc. C. E. Vol. XXI, p. 133.

To the question as to the George's Creek and Cumberland section, there is but one favorable response, that of Mr. Millholland, and that approves it only for roads of excessive curvature. Five others [Baker, Hinckley, Kingman, A. A. Robinson, Swift] approve the corner radius. All other responses disapprove the section, many of them with emphasis.

Question (1) above referred to the following summary of conclusions (the first one being slightly modified in form to make its intended meaning more clear) as to the causes of flange wear, from page 28 of the Committee's Preliminary Report:

"*First.*—That a tendency to eventually wear to a sharp flange is a natural phenomenon, which would exist and must exist in all perfect and perfectly running wheels, if there were no specific causes for it, and which cannot be eliminated by any form of rail or wheel.

"*Second.*—That imperfections of diameter of wheels or of trucks, or both, give a tendency to run to one rail or the other to nearly all axles, relieving half the wheels of flange-wear tendency, and aggravating that of the other half.

"*Third.*—That the quality of the wheel then has an enormous effect on the number of sharp flanges, causing many more when the fillet-chill is softer than the tread.

"*Fourth.*—That when the wheel is sound and the quality even, about half the wheels get sharp flanges, while this proportion is reduced as the number of special defects increases, which cut short the life of the wheel before it is worn out.

"*Fifth.*—That wheels which fail from flange wear are among the most durable of all wheels, if not the most durable, approximating to, if not exceeding, the life of those which fail from long-continued tread wear only, without developing other defect; so that no appreciable money loss results from wheels running to flange instead of failing from tread wear only."

To the question as to approval of this summary of laws of flange-wear the responses were:

Approving unconditionally	28
[Axtell, Barnes, Boon, Bouscaren, Brereton, Brown, Briggs, Carter, Crosby, Crowell, Delano, Fletcher, Forsyth (Robert), Gibbs, Hawks, Hitchcock, Hoyt, Howe (M. G.), Johnson (T. H.), Landreth, Man, McDonald, Penfield, Searles, Snow (J. P.), Stone, Swift, Whitcomb.]	
Approving, with comments and limitations, chiefly referring to the ambiguous original wording of the first statement, which is corrected above	9
[Baker, Burpee, Dudley, Katté, Merriman, Millholland, Pontzen, Thomson, White.]	
Approving, with limitations as to the fifth [Curtis]	1
Approving all but the first [Forsyth (William)]	1
Approving, with doubts as to third, fourth and fifth [Becker]	1
Approving by implication, but not answering categorically	11
[Blackwell, Buchanan, Darlington, Defrees, Hazlehurst, Jones, Loree, Newell, Otis, Richards, Voorhees.]	
Total approving unconditionally or in substance	51

Disapproving unconditionally..... 0

"Generally, no" [Bonzano]..... 1

Disapproving for the most part, although approving in part. 3

[Hinckley, Kingman and (A. A.) Robinson.]

Total disapproving..... 4

Question (2) of circular above was as to approval or disapproval of the Committee's preliminary conclusion expressed in the *italicized* words of the following quotation from page 35 of its Preliminary Report:

"If we remember in connection with the records just given: (1) that they included both inside and outside rails, only the latter showing a tendency to flange wear; (2) that the rails on the sharper curves were much younger than on the easier ones, so that the full contrast had not developed, and (3) that the rate of tangent rail-wear of the same rails seemed rather to decrease with age, these figures seem to your Committee to be strong evidence that *the rate of rail-wear grows very materially greater as the rail corner is rounded off to fit the fillet of the flange.*"

The responses showed:

Unqualifiedly accepting the conclusion..... 41

[Axtell, Baker, Barnes, Becker, Blackwell, Bonzano, Bouscaren, Brereton, Brown, Briggs, Buchanan, Burpee, Carter, Crosby, Crowell, Delano, Dudley, Fletcher, Forsyth (Robert), Gibbs, Hawks, Hitchcock, Hoyt, Howe, Johnson (T. H.), Katté, Loree, Man, McDonald, Merriman, Milholland, Otis, Penfield, Pontzen, Richards, Snow (J. P.), Snow (W. W.), Thomson, Voorhees, Whitcomb, Whittemore.]

Accepting conclusion with certain comments or limitations not appearing to affect the substance..... 2

[Searles, White.]

Accepting conclusion by implication from other answers as to form of rail sections, but not answering categorically..... 8

[Darlington, Defrees, Forsyth (William), Hazlehurst, Jones, Katté, Newell, Sloan.]

Total accepting conclusion explicitly or in substance.. 51

No by implication [Hinckley, Kingman, Robinson (A. A.)]... 3

Total not accepting the conclusion..... 3

Doubtful or experimenting [Curtis, Katté, Landreth]..... 3

Question (3) above, as to whether the engravings on pages 38 and 39 of the Preliminary Report (reproduced herewith), with personal observation and experience, warrant the conclusion that "worn rails in service

take a top radius of about 12 inches, seldom much more or less, and a corner radius of about ¼ inch, or somewhat more," is answered as follows:

12-inch top radius	36
[Axtell, Baker, Barnes, Becker, Bonzano, Bouscaren, Brereton, Briggs, Curtis, Delano, Fletcher, Forsyth (Robert), Forsyth (William), Hawks, Hinckley, Hitchcock, Hoyt, Howe, Johnson (T. H.), Jones, Katté, Landreth, Loree, Man, McDonald, Merriman, Millholland, Penfield, Richards, Searles, Snow (J. P.), Stone, Swift, Thomson, Whitcomb, White.]	
12 to 14 inches [Carter, Gibbs, Katté]	3
12 to 16 inches [Dudley]	1
12 inches or less [Brown]	1
12 inches with conditions not affecting substance [Burpee, Merriman, Pontzen]	3
12 inches by implication [Newell]	1
Total agreeing that natural wear is to about 12 inches radius	45
Dissenting, "wear nearly flat" [Darlington]	1
Dissenting—Worn rails in service do not take a top curve unless they have been turned [Crowell]	1
Dissenting without comment [Defrees, Hazlehurst, Whittemore]	3
Total dissenting	5
Not prepared to answer [Blickensderfer, Crosby]	2

As to the second part of the above question, whether wear tends to maintain about a ¼-inch corner radius, the responses stand:

Yes, ¼-inch radius	22
[Axtell, Baker, Barnes, Bonzano, Bouscaren, Brereton, Briggs, Carter, Delano, Fletcher, Forsyth (Robert), Gibbs, Hawks, Hitchcock, Hoyt, Johnson (T. H.), Landreth, Loree, McDonald, Millholland, Richards, Stone.]	
Not over ¼-inch [Katté, Voorhees]	2
Somewhat less than ¼-inch [Brown]	1
Somewhat more than ¼-inch [Howe, Snow (J. P.)]	2
¼-inch + $\frac{1}{32}$ [Forsyth (William), Penfield]	2
¼-inch to $\frac{5}{16}$ [Becker, Man, Thomson]	3
¼-inch to ⅜ [Merriman, Searles]	2
¼-inch with modifying comments [Dudley*]	1
⅜-inch [Hinckley, Kingman, Robinson (A. A.)]	3
⅜-inch to ½ [Curtis]	1
Total answering about ¼-inch in substance	39

* For light rails, $\frac{3}{32}$; for 60 to 75 pound rails, ¼; above that, $\frac{5}{16}$.

"⅝-inch" [Swift]..... 1
"Not proven" [White]..... 1
Total dissenting..... 2

About twenty of the responses either omit to answer this question or explicitly state that they have not examined into the matter enough to feel justified in expressing an opinion.

Question (4) above is as to whether the views expressed in the following quotations from page 44 of the Committee's Preliminary Report are warranted by the evidence:

"Is it desirable that the corner radii of rail and wheel in Figs. 9 and 10 should be nearly alike, or differ considerably? (See page 246.)

"So far as rubbing friction only is concerned there will be less wear if they differ considerably; so far as crushing action is concerned, there will be less as the radii approach each other. As a whole, it seems probable to your Committee that the very minimum rate may be when the fillet and rail radii are nearly alike, but not quite; but that they should be therefore made so in the beginning appears more doubtful for the following reasons:

"The evidence seems to be that under all working conditions the rate of rail-wear is very much less before the conditions of Fig. 11 are reached than afterwards. It is therefore desirable to postpone the attainment of such conditions as much as possible. But if the radii be made nearly alike in the beginning, we have but little metal to wear away before the conditions of Fig. 11 are attained. In proportion as the corner is originally sharper we have more. That is to say, if we take the total metal available for wear in the head at 10 pounds per yard or 1 square inch, by using for the corner radius:

½-inch	in place of	⅝-inch	we add	14.08	per cent.	to wearing	section.
"	"	¾	"	8.05	"	"	"
"	"	⅞	"	3.35	"	"	"

"If the preceding indications are correct as to this being very nearly the metal of slowest wear in the rail head, this is a serious loss, much larger than the above percentages alone indicate, and the question of which radius will give the lowest rate of wear in the new rail is less important than which gives the most metal to be worn away before the conditions of Fig. 11 obtain."

The responses stand as follows:

Approving unqualifiedly..... 31
[Axtell, Barnes, Becker, Bonzano, Bouscaren, Brereton, Brown, Briggs, Carter, Crosby, Crowell, Delano, Dudley, Fletcher, Forsyth (Robert), Forsyth (William), Gibbs, Hawks, Hitchcock, Hoyt, Howe, Johnson (T. H.), Katté, Man, McDonald, Merriman, Penfield, Pontzen, Searles, Stone, Thomson.]

Approving with limitations of minor moment..... 3
[Curtis, Landreth, Snow (J. P.)]

Approving by implication from other answers..... 9
[Buchanan, Darlington, Defrees, Hazlehurst, Jones, Newell, Richards, Voorhees, Whitcomb.]

Total approving..... 43

Disapproving explicitly..... 3
[Baker, Millholland, Swift.]
Disapproving by implication..... 3
[Hinckley, Kingman, Robinson (A. A.)]
Total disapproving..... 6

Question (5) above related to the views suggested in the following quotation from page 46 of the Committee's Preliminary Report, which quotation follows immediately after the one last given:

"The same reasoning, if sound, applies conversely to the fillet radius of flange. The larger this radius, the longer will it take to wear away enough metal to bring about the conditions of Fig. 11. (See page 246.) The most usual fillet radius some years ago was $\frac{3}{4}$ inch, but $\frac{5}{8}$ inch has lately been made standard by the Master Car Builders' Association, for the supposed purpose of approximating more nearly to the form of the rail-head, with some admitted disadvantage in manufacturing, because the smaller the radius, the more difficult it is to get a perfect chill in the fillet. If the preceding deductions are correct, a $\frac{3}{4}$-inch radius is rather to be preferred for all reasons; but there is no particular necessity from a mechanical point of view for having any single standard radius, either for rail or wheel (although of course it still remains highly desirable, for commercial and manufacturing reasons, to unify practice)."

[To avoid possible misconception, which appears in some of the discussions, the Committee has deemed it wise to add the words in parentheses to this quotation.]

The responses in regard to this question are:

Regard the conclusions as warranted..... 36
[Axtell, Baker, Barnes, Becker, Bonzano, Bouscaren, Brereton, Brown, Briggs, Burpee, Carter, Crosby, Crowell, Curtis, Delano, Dudley, Fletcher, Forsyth (Robert), Forsyth (William), Gibbs, Hawks, Hitchcock, Hoyt, Howe, Johnson (T. H.), Katté, Landreth, Loree, Man, McDonald, Penfield, Pontzen, Searles, Snow (W. W.), Stone, Thomson.]
Approve by implication..... 12
[Buchanan, Darlington, Defrees, Hazlehurst, Newell, Otis, Richards, Thomson, Voorhees, Whitcomb, White, Whittemore.]
Total accepting conclusions, explicitly or impliedly. 48

Dissenting explicitly..... 5
[Hinckley, Kingman, Millholland, Robinson (A. A.), Swift.]
Dissenting by implication [Boon, Snow (J. P.)]..... 2
Total dissenting..... 7

The Committee submits these views, which it has gathered as to fillet radius, for consideration on their merits; but inasmuch as there now exists a standard wheel section which has come into extensive use, it felt that it was inexpedient in this report to recommend any change in the existing standard.

Question (6) above relates to the suggestion of an entirely flat top between the rounded rail corners. One vote on this question (approval or disapproval of a 12-inch top radius) is recorded in the body of this report, but as the vote on the direct question differs somewhat, it is here given, as follows:

In favor of a flat top	7
[Blackwell, Darlington, Defrees, Hazlehurst, Howe, Morris, Whittemore.]	
In favor, with qualifications [Crowell]	1
Inclined to favor a flat top [Axtell, Baker, White]	3
Total favoring a flat top	11
Disapproving a flat top	36
[Barnes, Becker, Bonzano, Bouscaren, Brereton, Brown, Briggs, Buchanan, Carter, Curtis, Delano, Dudley, Forsyth (Robert), Forsyth (William), Gibbs, Hawks, Hinckley, Hitchcock, Hoyt, Johnson (T. H.), Jones, Katté, Kingman, Man, McDonald, Merriman, Millholland, Pontzen, Richards, Robinson (A. A.), Sloan, Snow (J. P.), Stone, Swift, Thomson, Voorhees.]	
Disapproving by implication [Loree, Newell]	2
Disapproving for coned wheels; otherwise doubtful. [Whitcomb.]	1
Total opposed to a flat top	39
Doubtful; "as nearly flat as possible, say 18 inches" [Burpee, Fletcher, Johnson (J. B.), Landreth.]	4

The matter contained in this Appendix might with propriety have been included in the Committee's report, and is to be considered as a part thereof, but as it did not relate to their final recommendations, but only to premises on which to base such recommendations, the Committee concluded to confine its report to specific recommendations only. As of probable interest in this connection, the Committee append herewith a drawing of the present Master Car Builders' standard wheel tread. (Fig. 4.)

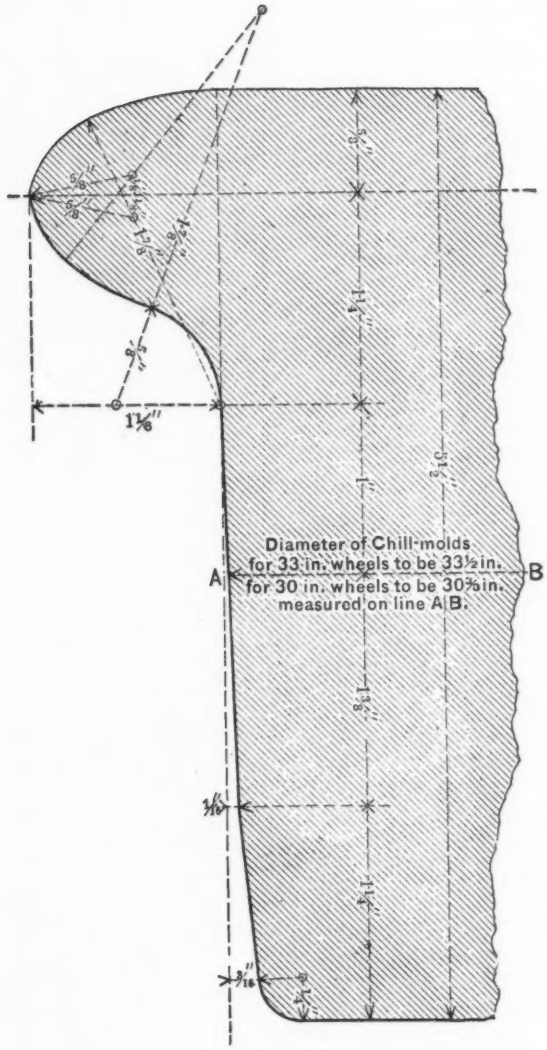


FIG. 4.—MASTER CAR BUILDERS' STANDARD WHEEL TREAD SECTION.

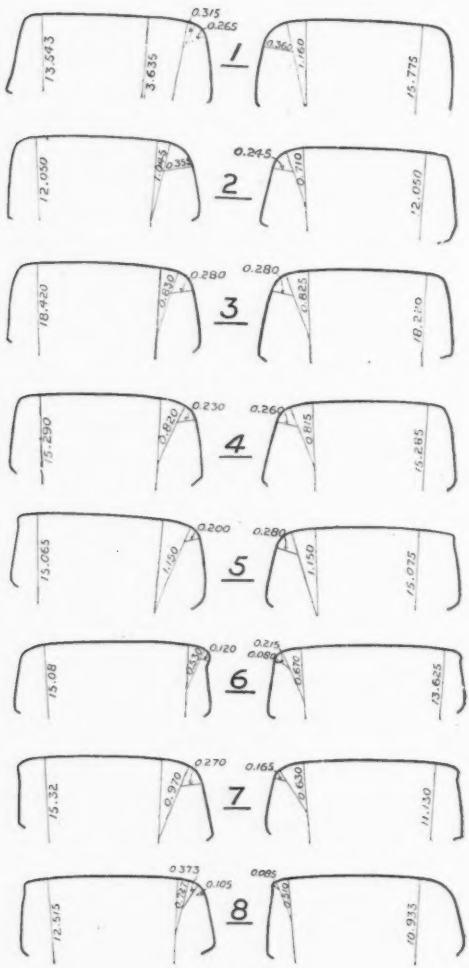


FIG. 7.

RADII OF WORN SURFACE OF RAILS IN SERVICE, PENNSYLVANIA COMPANY. TANGENT RAILS.

[Reproduced from the Committee's Preliminary Report.]

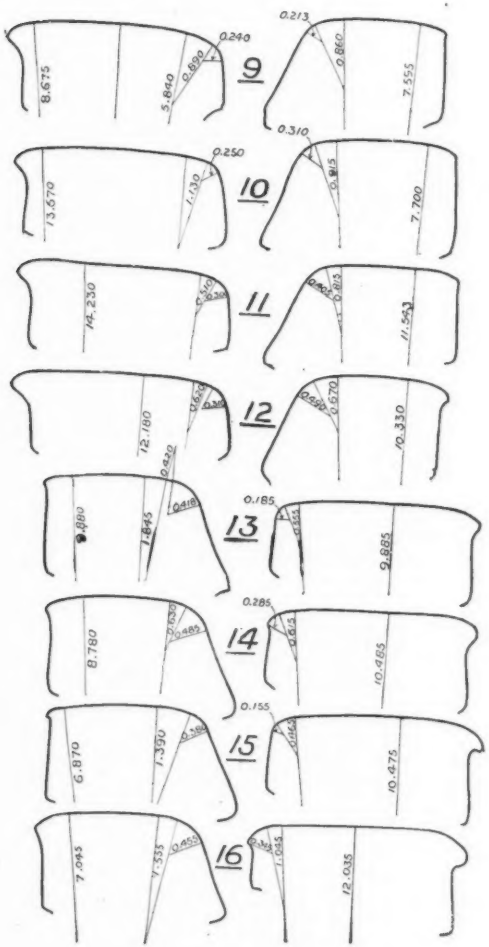


FIG. 7—*Continued.*

RADII OF THE WORN SURFACES OF THE RAILS IN SERVICE, PENNSYLVANIA COMPANY.
INSIDE AND OUTSIDE RAILS OF CURVES.

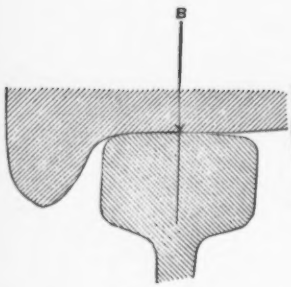


FIG. 8.

Flange acted on by little or no lateral force, but as close to rail as its form permits without such force.

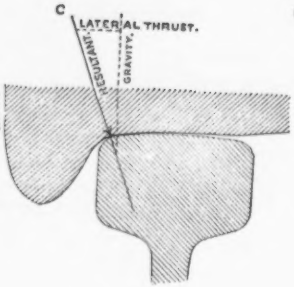


FIG. 9.

Flange acted on by a MODERATE lateral force, as by impacts or oscillation on tangents. (The line C gives the resultant line of pressure, perpendicular to the bearing surfaces in contact.)

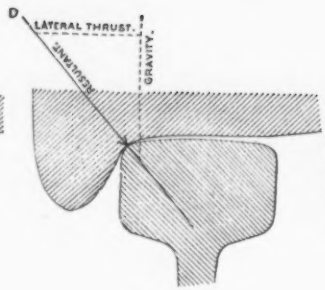


FIG. 10.

Flange impelled against the rail by a STRONG lateral thrust, as on outside rail of curves. (The line D gives the line of pressure, still perpendicular to bearing surfaces in contact. The wheel rises as shown until they become so.)

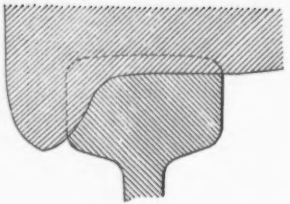


FIG 11.

Worn outside rail on curves, having the bearing surfaces worn to conform to each other, as in Fig. 2 of Preliminary Report.

[Reproduced from the Committee's Preliminary Report.]

APPENDIX B.

The following extracts are made from letters received in addition to categorical replies to the questions of the circulars issued by the Committee:

M. J. BECKER, President Am. Soc. C. E.—If it is admitted that the flanges of wheels (no matter how small their number may be in proportion to the entire lot) are becoming sharpened by use, then it cannot be denied that the primary cause for their being so sharpened is on account of their contact with the rail heads while rolling over the track. Imperfect diameters, oblique trucks, and improper gauging may aggravate the result, but they are not the original causes. I agree with the first conclusion of the Committee, as stated on page 28,* that this result cannot be eliminated by any form of rail or wheel; and I also admit the second one of the Committee's conclusions. But while I am not prepared to controvert, from personal experience or trustworthy information in my possession, the correctness of the third, fourth and fifth conclusions on the same page, I am not ready, from the data appearing in the report, to accept them as final. Generally speaking, I have always been of the opiuion that the rail section is affected by the wheel flanges to a much greater extent than the wheel flanges are affected by the rail section; the rail metal being much softer than the chilled wheel metal, the rail would seem naturally to suffer most from the contact.

My experience corroborates the conclusions of the Committee on page 35, that the rate of rail wear increases with the increased contact area, caused by the rounding of the corners of the rail to fit the fillet of the wheel flange. This is certainly true as far as the outer rail on curves is concerned. I have noticed often that upon a portion of our line, composed largely of 9 and 10 degree curves, the inner face of the head of the outer rail was being rapidly planed off as in a lathe, after an impression had once been made, and that the track was thickly strewn with the shavings and small clippings planed off the rail head by the rubbing action of the wheel flanges. I have never noticed a similar effect upon tangents and lighter curves, but upon general principle the conclusions of the Committee would seem rational.

I have never seen a rail worn entirely flat on top. Mr. Rodd's illustrations compare very closely with some samples collected by myself; one of these I inclose (see Fig. 5). The rail was made at the Cleveland Rolling Mill and sold as second quality on account of its supposed hardness; it was laid in the Columbus Depot Yard in 1873, and was literally worn down to nothing when removed about two years ago. The rail was without a flaw throughout, and wore remarkably uniform under a very heavy but irregular traffic in and around the passenger station.

* Preliminary Report, Transactions, Vol. XIX, July, 1888.

A top curve, with a radius of 12 inches, and corners with radii of from $\frac{1}{4}$ to $\frac{5}{16}$ inches would seem to me about the proper shape for a rail head.

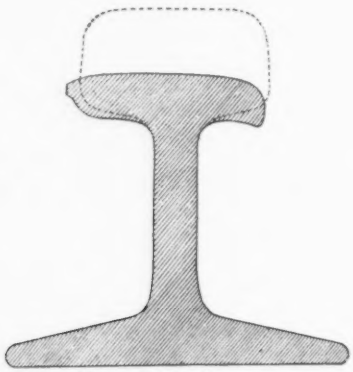


FIG. 5.

Second-class steel rail made by Cleveland Rolling Mill Company and laid in Union Depot tracks at Columbus, O., 1873. Taken up 1887. Dotted line shows original section. This rail carried all of the L. M. R. R. freight traffic and a large amount of switching for fourteen years.

The conclusions of the Committee on page 44 seem to me warranted. The wheel tread should fit the rail top for as great an area as possible; the wheel fillet should be of slightly larger radius than the rail corner, and the sides of the rail head made nearly or quite vertical so as to prevent, for the longest possible time, the close rubbing contact between wheel flange and rail head.

I consider the standard rail section of the Michigan Central Railroad a very good one in every particular, unless it should be found that the shoulder under the rail head is insufficient for the angle bar, in which event I would increase the top width, but leave the sides of head vertical, and, if necessary to maintain the weight, would shave the web a trifle.

The object of Mr. Whittemore's flat head rail sections is to obtain larger bearing surface and thereby relieve the rail from the excessive wheel pressure. This is certainly desirable, and theoretically the flat head would accomplish the object, but I would apprehend that, even with a perfectly flat rail head in general use, the wheel treads would still continue to wear somewhat hollow, and, if so worn, would ride on one or both edges of the flat-headed rail instead of the entire top, and thereby fail to accomplish Mr. Whittemore's purpose; eventually they would, I think, wear the rail top round to conform to their own grooved shape.

W. S. G. Baker, President Baltimore Car Wheel Company.—I regret that I am unable to give an opinion from practical knowledge or experience, except to say that I fully concur with observation First, upon page 28 of Transactions of Society for July, 1888, but believe with properly made wheels, round in form, uniformly chilled, well paired, and properly placed in trucks with load centrally placed so loads will not overhang center line of draft, flange wear will be comparatively small, regardless of form of rail heads.

The only reason why a flange-worn wheel would show a greater per cent. of service is, that they have better wearing qualities upon tread—others being either lightly chilled on tread or defective from special causes—in other words, improperly made.

I believe that chilled wheels can be made that will give even wear and be free (practically) from special defects.

I regret, as a wheel manufacturer, to admit that the chilled wheel in general use is not properly made; and hold the railroads responsible for such state, as price and not quality govern their purchases in large degree.

Oliver W. Barnes, M. Am. Soc. C. E.—I take the opportunity to inclose a section (see Fig. 6) of standard pattern of 60-pound rail which I have just designed and adopted for the Baltimore and Drum Point Railroad, 80 miles long. The peculiar feature of this rail pattern

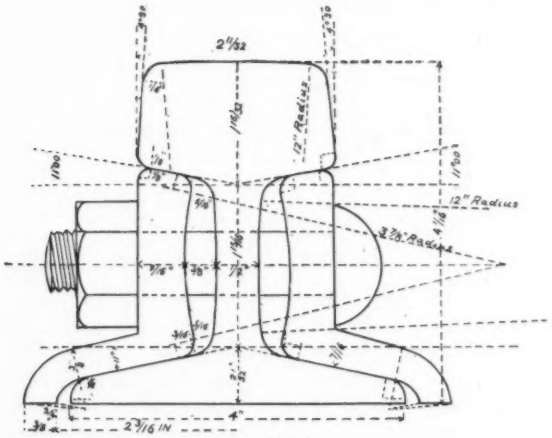


Fig. 6.

is in the angle under the head of 11 degrees, which is the smallest of any rail pattern that has ever been used that I am aware of. If this proves satisfactory, I intend in the future to use a still less angle.

The angle bars used with this rail are somewhat different from those in use on the Pennsylvania Railroad, inasmuch as the Pennsylvania Railroad Company use six holes in each joint, whereas I consider four as amply sufficient.

CHARLES BLACKWELL, M. Am. Soc. C. E.—Sharp flanges are caused by disparity in circumferences of the individual wheels forming a pair. I advise an entirely flat top with maximum of width, and in conjunction, entirely cylindrical wheels, so far as the rail bearing is concerned.

VIRGIL G. BOGUE, M. Am. Soc. C. E.—The accompanying sketch, Fig. 7, of our (Union Pacific R. R.) 75-pound rail section, practically illustrates my view of what the rail section should be.

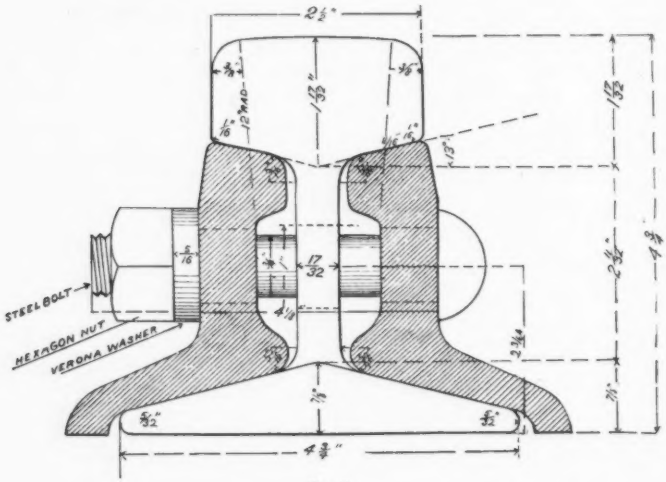


FIG. 7.

	Square inches.	Per cent.
Area of head	3.36	46
" web	1.32	18
" flange	2.67	36
Total area of rail	7.35	100

I prefer the 12-inch top radius because I believe the rail will wear to about that shape, even with cylindrical wheels. I am inclined to think the ¼-inch top corner radius used in the Michigan Central standard is a little too small. I believe it will rapidly wear away the wheel fillets, and therefore prefer ⅜-inches. I prefer vertical sides for head of rail. I prefer small lower corner radius, but at this time I think ½-inch about right for it. I believe rails will roll better

when this radius is not quite so small as in the Michigan Central standard, or as shown in Fig. 7. I prefer vertical sides for web of rail, because I believe the rails will roll better and last longer when so made. I have never heard any good reason for making these sides curved, as is usually done. Metal is needed at center of web to sustain heavy blows.

In my opinion, the reduction of metal in the head to 41 per cent. of the whole, as shown by Michigan Central standard, is too much of a good thing. We have used 46 per cent. in the belief that we shall get equally good results in the manufacture of the rails and better results as to wear.

I am inclined to think the general conclusions of the Committee as to wheel and rail wear are about correct, but have not given the matter the attention required for positive opinion.

If we were to revive our 75-pound rail section and joint we should make the lower corner radius of head $\frac{1}{8}$-inch; would make the bolts 1 inch in diameter, and the angle bars at least 42 inches long. They

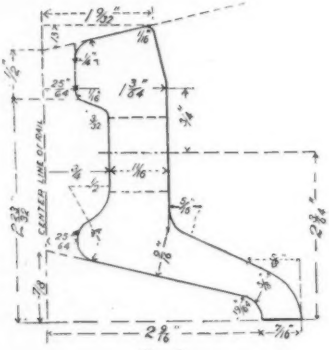


FIG. 8.

NOTE.—One pair of angle bars weighs 70 pounds.

are now 40 inches long. In my judgment there is no gain in leaving a space between the tie and lower flange of angle bar. In practice, the rail soon cuts the tie enough to bring the angle bar to a bearing on it. I prefer to have this bearing exist from the start.

G. BOUSCAREN, M. Am. Soc. C. E., makes the following annotation in addition to his answers to the questions of the circular, as elsewhere recorded:

Decrease width of flange, making thickness on edges not less than $\frac{3}{8}$-inch; allow $\frac{1}{4}$-inch for wear off top of head and make remaining area *B* equal to area of flange *C* (see Fig. 9).

The engravings of worn wheels and my own experience warrant the conclusion that worn rails in service take a top radius of about 12 inches, seldom much less or more, and a corner radius of about ¼-inch, or somewhat more. Old wheels with grooved treads tend to give a

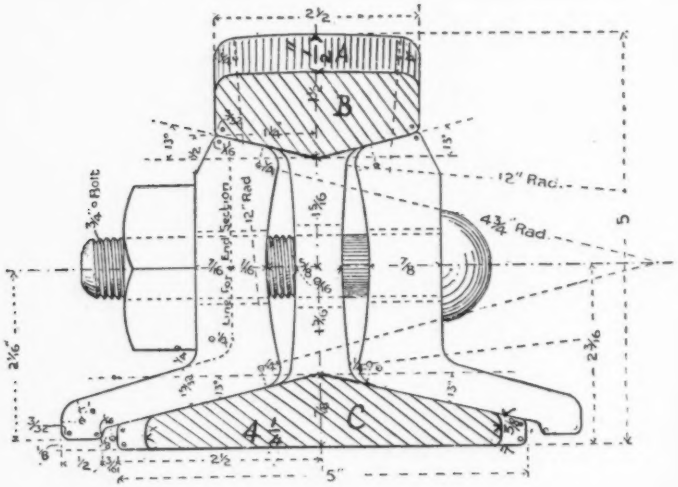


FIG. 9.

surface of smaller radius; the more perfect the wheel the longer the radius. With perfect cylindrical wheels I would be in favor of flat top heads; the point of greatest importance is to secure the largest possible area of contact between tread and head. So long as it is not possible to maintain the majority of wheels in a perfect cylindrical condition, I would not recommend an entirely flat top.

THOMAS J. BRERETON, Jun. Am. Soc. C. E.—According to my experience your committee has reached proper conclusions with regard to relative forms of flange and rail head. I suggest the following objections to the form of rail illustrated (Michigan Central Standard). The vertical sides allow less shoulder for the splice bars than sides which slope outward for the same width of head on top. The splice bars therefore project too far from the rail, and after the already slight depth has been decreased by wear a very little, the flanges of wheels will strike upon the splice bars, and in cold weather this may break pieces from the flange and produce disastrous results.

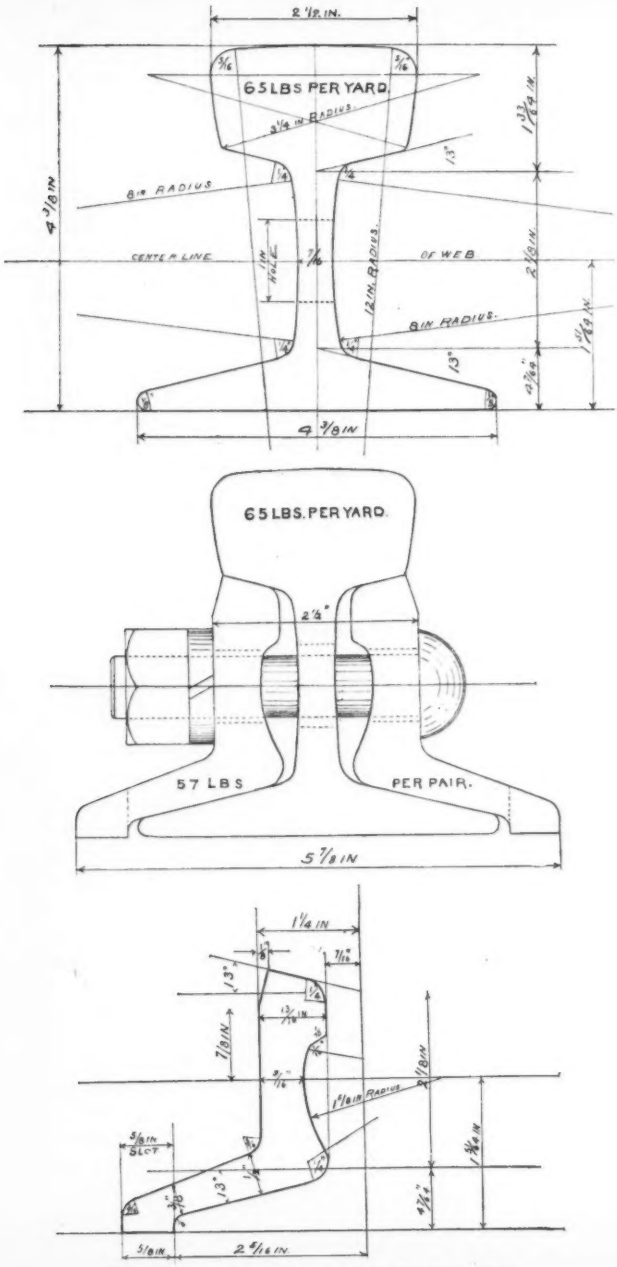


FIG. 10. – 65-pound rail, Denver and Rio Grande Railroad.

I could point out to your committee a great many curves upon our road (Pennsylvania Railroad) where this process has been going on upon the outside rail, and in some instances where a groove has been planed out of the projecting top of the splice bar from ¼ to ⅜-inch deep by this action. This always occurs where we have placed the recent heavy splice bars (our No. 4 pattern) upon rails of the old 60 and 70-pound Pennsylvania Railroad standard section, which possessed greater depth of head and less projection of splice bar than the illustrated pattern of your circular.

I approve of the 12-inch top radius and ½-inch corner radius, as illustrated.

I should consider the Michigan Central standard better if the head were ½-inch higher and the sides flared out about 3 or 4 degrees.

The Pennsylvania Railroad has tried and discarded very nearly the same section as the Lehigh Valley. The high and large head is especially objectionable.

The George's Creek and Cumberland section is, I think, very bad.

R. E. Briggs, M. Am. Soc. C. E.—I enclose sections of our 65-pound rail, adopted by the Denver and Rio Grande Railroad, June 26th, 1888. (Fig. 9.)

To secure the broad head and keep the weight of the rail within such limits as would be approved, the sides of the head were inclined toward the base of the rail and the lower corner made sharp to increase the bearing surface on the angle bars. This was done with the idea of putting the metal in the head where the greatest wear comes. We have laid nearly 20,000 tons of this pattern, and thus far the results have been very satisfactory. I do not deem an entirely flat top likely to be effective in reducing rail wear. So far as my experience and observation goes, 12-inch top radius is about right.

W. H. Brown, Chief Engineer, Pennsylvania Railroad Company.—We do not advise recommending an entirely flat top, because the corners of a flat top rail would wear away rapidly, while a curved top would fit the tread better.

Moses Burpee, M. Am. Soc. C. E.—I would not expect sharp flanges to be caused by rails shown in Figs. 2 or 3 of the Committee's preliminary report, but would by Fig. 1, at least until the whole inside surface of flange was worn to the very edge; the other conclusions, on page 28, I think reasonable.

I should think that the top radius of rail caused by wear was determined by the average shape, etc., of the wheels which passed over it, and a different radius might result if a largely predominating proportion of the rails were at first rolled to a different radius, or that the effect of wear of wheel from certain shapes of rails is to wear other rails to a like shape.

I recommend an entirely flat top, if practicable, or as nearly so as possible. With a wheel and rail that are made to present the largest practicable bearing on each other, it seems fair to expect both to last longer than when the bearing is very much less. I would rather have the largest possible crown radius that could be made without loss of a proper degree of solidity of metal in the head of rail; believing also that if a flat top rail could be properly made it would, with flat wheels, give better results than the present practice, but that, should it ever be proven that this is so, it must be done by gradual changes in both rails and wheels, which changes should be in the same direction.

I think that the wear of wheels indicated, as to a radius of 12 inches, a good reason for belief that with a flat top rail in general use, the wear would be flat also on the wheels.

EDWARD C. CARTER, M. Am. Soc. C. E.—The Committee's conclusions are, for the most part, correct. I think that 14 inches would be nearer the proper curve than 12 inches; ½-inch corner radius is all right.

I do not at all approve the idea of an entirely flat top. A flat rail would very soon be worn to a rounding top surface, with a very considerable loss of metal. This would be the case even if you started with new wheels and rails, respectively cylindrical and flat headed, for the wheels will wear away into a groove and then wear down the edges of the rails to correspond.

WILSON CROSBY, M. Am. Soc. C. E.—In addition to his recorded responses to questions of circular, states that he prefers a top flatter than 12 inches for cylindrical wheels, but with coned wheels a 12-inch radius of rail top may do; also that he deems an entirely flat top between the rail corners likely to be effective in reducing rail wear with cylindrical wheels, but with coned wheels, doubtful.

He sees no gain from the curve or objection to making the rail top flat instead of slightly curved, if the flat top of the rail can be as readily rolled, and he advises recommending an entirely flat top, or nearly so, between wheels not coned, but with coned wheels should prefer a 12-inch radius for the top.

J. FOSTER CROWELL, M. Am. Soc. C. E.—The preliminary report of the Committee has been carefully studied from the point of view which it suggests.

As it seems to me, your Committee shows an inclination to adopt a compromise which shall most fairly meet all the conditions in wheels and rails as they now exist; and to make only such recommendations as may be followed without materially affecting the manufacture of them. It is not my intention to question the wisdom of such a tentative course, and it may well be that the hour is not here, nor the man, for more radical changes which, sooner or later, probably must take place. If, in the final

rendering of the Committee's report, the preliminary conclusions are confirmed, the question, in so far as it affects the rail head, will have been decided according to the extreme conditions pertaining to outer rails on curves, as rails are at present made and laid, leaving untouched the grave suggestiveness of that wear as to whether the rails for curves should not be differentiated in form or position, or both; it is of course to be admitted that the customs now prevailing in rail manufacture and supply do not give much encouragement in such a direction, but it would seem that the additional stress on outer rails or about 12 per cent. of all rails, should be provided for before disposing of the matter.

With such reservation as to scope, I send reply to the questions which you put.

I add that I do not consider that worn rails in service take a top curve unless they have been turned; the curve then results from the composite effect of the coning of the majority of the wheels, tending to wear the inner half of the rail head and of flattening along the center of rail by occasional straight treads or treads grooved by wear. I should say that the engravings on pages 38 and 39 (Trans., July, 1888) do not illustrate the primary effect so well as Figs. 32 and 33 on page 6; Fig. 32 showing the primary effect, while Fig. 33 appears to be a rail that has been turned.

The evidence appears to warrant the preliminary conclusion as to fillet radius on page 45. This is a question so largely of manufacture that the wheel makers may be safely left to themselves to evolve the best wearing fillet, provided its form does not react upon the rail corner; the evidence is, however, clear that the larger radius is best for the rail.

In answer to the question in regard to Mr. Whittemore's proposed top, entirely flat between rail corners, I would say that I am greatly in favor of dispensing with the curve, provided the coning of the wheel is abandoned also, as he recommends. Under those circumstances I should recommend an entirely flat top, and see no objection whatever to making it so.

W. G. Curtis, M. Am. Soc. C. E.—The various divisions of the Pacific system lines of the Southern Pacific Company, in the States of Oregon, California and Nevada, and the Territories of Utah, Arizona and New Mexico, aggregating 4 250 miles in length, present a wide diversity of physical characteristics.

Many of the divisions have steep grades and crooked alignment, and some of the others lie on easy grades and comparatively straight lines. The Central Pacific through line crosses the Sierra Nevada Mountains at an elevation of 7 017 feet above the sea; 60 miles of the Southern Pacific on the Colorado Desert, in Southern California, lie below ocean level, the lowest point being — 266 feet. The minimum winter tem-

perature in Nevada is about 60 degrees below zero, and the maximum summer temperature in some parts of Arizona is over 120 degrees above zero, Fahr. The mean annual precipitation (rain and melted snow) in some portions of Central and Northern California is considerably over 50 inches, and in Western Arizona it is less than 3 inches.

The motive power consists of locomotives of many classes, ranging from those with a single pair of drivers and weighing 15 tons, to those of the "El Gobernador" type, with five pairs of drivers and weighing 77 tons.

These, as well as other great differences in conditions, cause many of the operating problems to present themselves, chameleon-like, in various colors according to the surroundings of the observer, and as a necessary consequence from this state of facts, our general and division officers are not so well agreed as we could wish upon some of the facts required by the gentlemen of the Committee. But I may say, as the result of our observation and experience, that we consider, as to sharp flanges, that the conclusions of the Committee are correct, and in this connection I submit the following, which we regard as conclusive evidence on this point:

Statement of steel tired and cast-iron car wheels in six-wheeled trucks, removed from under passenger stock at Oakland, Cal., account condemned for sharp flanges under Master Car Builders' rules, from January 1st, 1884, to November 28th, 1887.

	Number of pairs with		
	both wheels sharp flanged.	one wheel sharp flanged.	Total pairs.
Number of pairs of wheels on outside axles....	14	99	113
" " inside axles.....	15	72	87
" " middle axles....	9	126	135
	38	297	335

The Committee considers "That wheels which fail from flange wear are among the most durable of all wheels, if not the most durable, approximating to, if not exceeding, the life of those which fail from long-continued tread wear only without developing other defect; so that no appreciable money loss results from wheels running to flange instead of failing from tread wear only."

This conclusion appears to be correct for chilled cast-iron wheels, according to our experience, evidenced by the accompanying statements of wear of numbered wheels. In connection with these statements I should explain that, April 30th, 1881, we commenced putting in service numbered, Southern Pacific standard, cast-iron wheels. From that date up to April 30th, 1885, we had put in from time to time, all told, 29 114 new numbered wheels not ground, 4 114 new wheels ground and 5 136 old wheels ground. The old wheels in question had no numbers before

being ground, but were assigned numbers after being ground and fitted for further service. 27 114 of the new ground and unground wheels were manufactured in the Southern Pacific Company's wheel foundry at Sacramento, Cal., and 2 000 of them were made by the Ensign Manufacturing Company, Huntington, W. Va. All of these wheels were Southern Pacific Company standard, having a ¾-inch fillet radius. The make of the 5 136 old wheels (which were withdrawn on account of defects in tread, and afterward fitted for further service by being ground or "turned true" in a wheel grinding machine) is not known.

Unquestionably, however, the tendency to run to sharp flange shortens the life of cast-iron wheels on crooked mountain divisions, because, other things being equal, this tendency for leading wheel to run to outer rail of a curve, acting in the same direction with other forces, causes the flange on such wheel to wear more rapidly than would be the case with a more perfectly running wheel.

Again, this conclusion, for our average conditions, is not true of steel-tired wheels. Our records are not very extensive or complete in this connection, but we believe the following computation, based on the actual service of ten 42-inch, steel-tired paper wheels, fairly represents the average service of such wheels, and I believe we are very near the truth in saying that wheels of this description would make double their present actual mileage on our line were it not necessary to take them out on account of sharp flanges and turn them in the shop after about each 100 000 miles run.

MILEAGE LOST ON ACCOUNT OF SHARP FLANGES ON 42-INCH PAPER WHEELS.

Mileage made by ten 42-inch paper wheels, as per statement of April 2d, 1889	4 525 994
Average mileage per wheel	452 599
Average number of times each wheel turned	4.4
Number of miles made to each turning	102 863
Number of times each wheel can be turned (assuming ⅛ inch only as actual wear on tread at time of turning)	8
Number of miles each tire should make if turned for wear on tread only	822 904
Actual mileage per wheel	452 589
Mileage lost by turning wheel, account sharp flange	370 305

Regarding the proposition "that the rate of rail wear grows very materially greater as the rail corner is rounded off to fit the fillet of the flange:"

Our observers here are not agreed on this point, but the weight of the evidence indicating the experience of this company seems to lead to the opposite conclusion. I consider further experiments are needed

to settle the matter beyond all question or doubt, and to that end we have put into service quite a number of rails shaped down to forms indicated by the accompanying sections, Figs. 1, 2, 3, 4, 5, Plate LXXI, the gauge side of rail varying from a vertical line to one inclined about 77 degrees from the horizontal and with the top corner of curve on the gauge side ranging from $\frac{1}{8}$ to $\frac{5}{8}$ inch radius. These rails are from the same lot and supposed to be quite uniform in quality. To eliminate nearly all doubt as to difference in quality of the metal, so far as it cuts any figure in the experiment, some 30-foot rails have been cut into two and three pieces and the different pieces planed out to different forms; these rails have been laid on outside of curves. The tonnage over them will be recorded and the rate of wear, with all other essential facts, carefully observed. I regret the resulting data will not be available for immediate use by your committee.

As to radius of top curve of worn steel rails, our experience confirms the committee's conclusion, that this worn top curve has a radius of "12 inches, seldom much less or more." The wear of "corner radius," however, according to our observation, averages somewhere between $\frac{3}{8}$ and $\frac{1}{2}$ of an inch, as indicated by what we regard as typical worn sections, sent you herewith (Plate LXXI, Figs. 6, 7, 8).

Referring to questions on page 44 of the report of Committee:

"*First.*—Will there be more or less grinding friction or abrasion under the conditions of Fig. 10 or under those of Fig. 11?"

"*Second.*—Is it desirable that the corner radii in Figs. 9 and 10 should be nearly alike, or differ considerably?" (See page 246.)

It is quite plainly evident that, while the conditions continue to be practically those of mere rolling friction, as in Fig. 10, the abrasion will be at a less rate than for the sliding contact indicated by Fig. 11; but, especially for outer rail of curves on a crooked road, it is somewhat doubtful whether the conditions of rolling contact in question can be maintained for any considerable length of time, and when the element of sliding friction begins to appear the sliding takes place under much greater pressure per unit of surfaces in contact than it afterward becomes under the conditions indicated by Fig. 11. It seems, therefore, as above stated, that further experiments are very much needed in addition to the information written down in the committee's preliminary report, before the conclusions outlined in that report can either be confirmed or disproved.

Regarding the wheel fillet radius, the standard of our road is $\frac{3}{4}$ of an inch, and regardless of all other considerations, we shall doubtless continue to prefer this curve as permitting the production of wheels with a better and more uniform chill than obtainable when using curves of a shorter radius.

Mr. Whittemore's paper referred to, proposing cylindrical wheels and flat top rails, seems to agree with theoretically correct conclusions;

yet it is evident that with wheels and rails of this description, if the rail is inclined inward or outward to the slightest extent, contact between wheel and rail top is reduced enormously, and the moment or leverage of a heavy wheel on one side of a wide rail top has, especially on tangents, a tendency to break off one side of the rail head. In other words, to realize the advantages Mr. Whittemore claims for his design, the flat tops of both rails must lie in the same plane which must be coincident with a "horizontal" plane tangent to the wheel treads in contact with the rail. It is very doubtful whether it is practicable, with ordinary care in maintenance, to provide for this perfect condition and adjustment of wheels and rails.

The conditions of contact, other things being equal, can be accomplished with flat top rails and ordinary coned wheels, coning about 1 in 20 inches, almost as well as by the proposed cylindrical wheels, by inclining the rail inward toward the center line of track (as illustrated by Fig. 9, Plate LXXI), which indicates the practice of this road on mountain divisions and to some extent on valley divisions, new ties being "spotted" by machinery to carry the rail in the position shown.

Fig. 10, Plate LXXI, shows about the average form of all locomotive driving wheel tires in service on our lines. Fig. 11, Plate LXXI, indicates the same thing for a badly worn driving wheel tread. Referring to Fig. 10, it is evident that the rail may be inclined either inward or outward to some considerable extent, and yet with a round topped rail (either section shown in Fig. 9 or Michigan Central section on page 234 *ante*) and driving wheel tires in average condition, there is an opportunity for the wheel to take such a position as will bring a considerable portion or its tread and the rail top in contact, thus giving reason to believe that under average conditions, with comparatively light rails used on the greater portion of the mileage of the country, there is as likely to be as much of the wheel tires and rail tops in contact under the coned wheel round rail top practice as with the cylindrical wheel and flat rail top design proposed by Mr. Whittemore.

I am in confident expectation that my friends and fellow-members of our Society east of the Rocky Mountains, who have so much better opportunities so to do than we of the extreme West, will conduct the exhaustive practical experiments, which certainly seem to be necessary to clear away all doubt from this most interesting branch of the subject.

Plate LXXII shows sections of iron rails in track of the Sacramento Division of the Central Pacific Railroad.

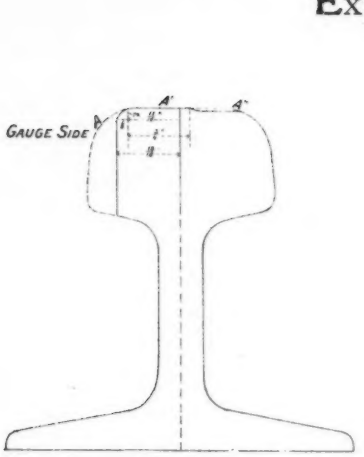
SOUTHERN PACIFIC COMPANY.—SERVICE OF ALL NEW NUMBERED 33-INCH CAST-IRON CAR-WHEELS, NOT GROUND FOR FOUR YEARS, ENDING APRIL 30TH, 1885.

		TOTAL MILEAGE.	AVERAGE MILEAGE.	
Total number in service.....29 114				
Passenger wheels condemned.....	2 421	144 477 963		
Freight wheels condemned.....	2 713	56 374 268		
Total wheels condemned.....	5,134	200 852 231	39 122	
Cost per wheel.....		.....	.....	$8.50
Cost per mile.....		.....	.....	.00022
Of wheels condemned, 788 or 15 per cent. sharp.....		50 535 394	64 131	
Of wheels condemned, 348 or 7 per cent. worn out.....		23,530 717	67 617	
Of wheels condemned, 3 998 or 78 per cent. other causes.		126 786 120	31,712	
WHEELS IN PASSENGER SERVICE.				
Of wheels condemned, 696 or 28 per cent. sharp...		46 317 460	66 548	
Of wheels condemned, 245 or 10 per cent. worn out,		18 606 815	75 946	
Of wheels condemned, 1 480 or 62 per cent. other causes.....		79 553 688	53 752	
Total wheels condemned,	2 421	144 477 963	59 677	
Cost per wheel.....		.....	.....	$8.50
Cost per mile.....		.....	.....	.00014
WHEELS IN FREIGHT SERVICE.				
Of wheels condemned, 92 or 3 per cent sharp....		4 217 934	45 847	
Of wheels condemned, 103 or 4 per cent. worn out		4 923 902	47 405	
Of wheels condemned, 2 518 or 93 per cent. other causes.....		47 232 432	18 757	
Total wheels condemned,	2 713	56 374 268	20 779	
Cost per wheel.....		.....	.....	$8.50
Cost per mile.....		.....	.....	.00041

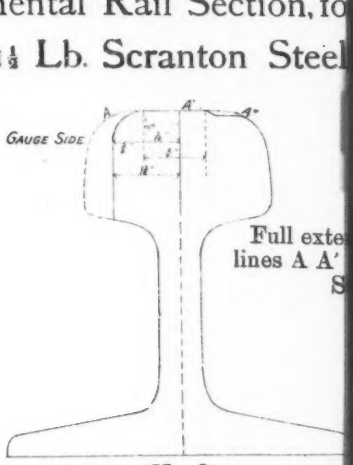
SOUTHERN PACIF

Experimental Rail Section, fo

61½ Lb. Scranton Steel



No. 1.



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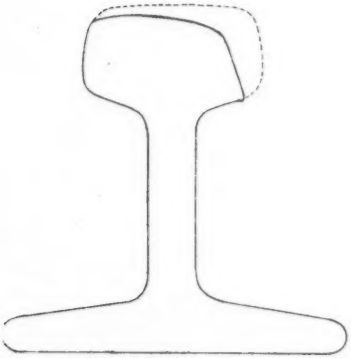
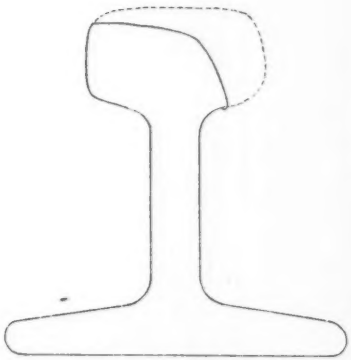


Outside Rail.
Fig. 6.



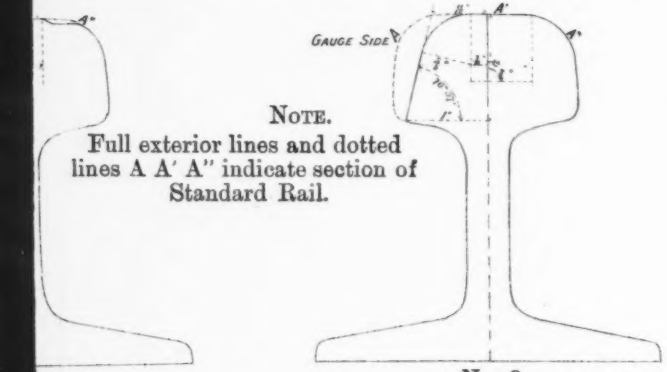
Outside Rail.
Fig. 7.

Cambria Steel Rail, 60 lb. per yard, removed from track Sacramento Division, Central Pacific R. R., August, 1883. Laid on Curve 8° 20', L. No. 204, near Towles Station, November, 1874.

ERN PACIFIC COMPANY.

Section, formed by Planing down

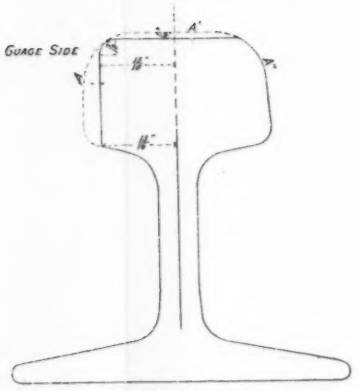
ton Steel. Pattern 1882.



2.

NOTE.
Full exterior lines and dotted lines A A' A" indicate section of Standard Rail.

No. 3.



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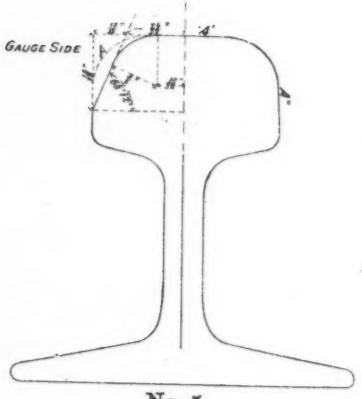


No. 5.

Rear Driver Central Pacific R
No. 229 after running 18107
Weight on Wheel, $6\frac{62}{100}$ tons.

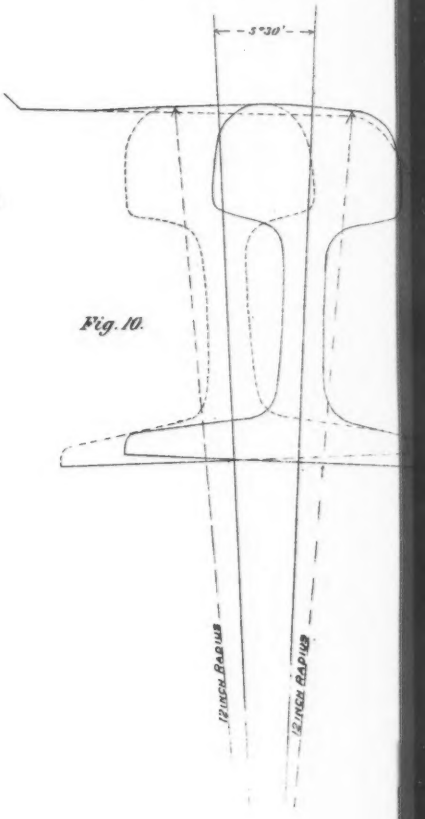
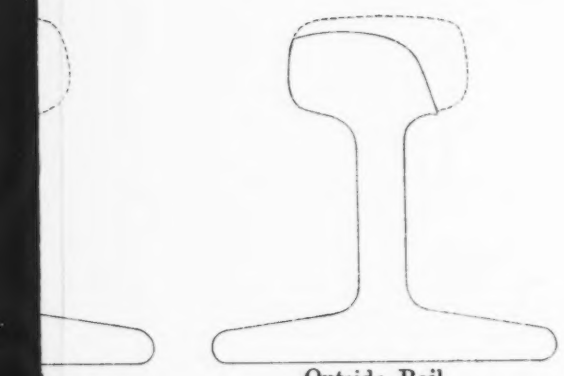


Fig. 10.



Outside Rail.
Fig. 8.

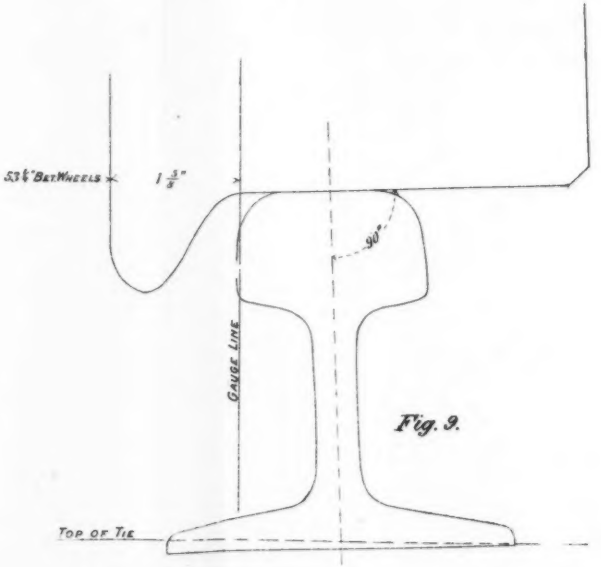
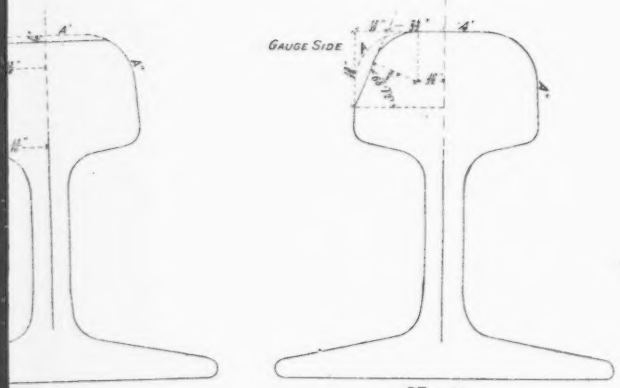


Fig. 9.

n track Sacramento
d on Curve 8° 20'. L.
er, 1874.



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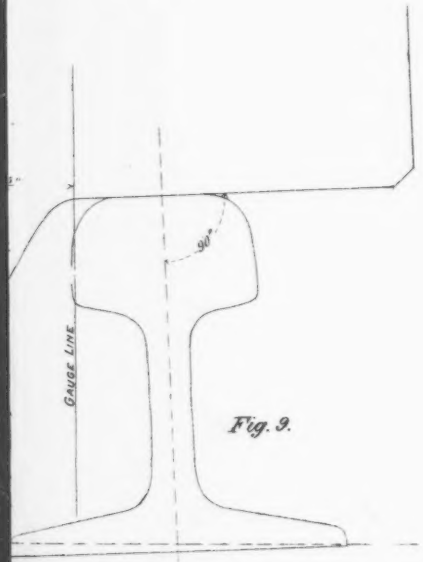


Fig. 9.

Rear Driver Central Pacific Engine
No. 229 after running 18107 miles.
Weight on Wheel, $6\frac{62}{100}$ tons.

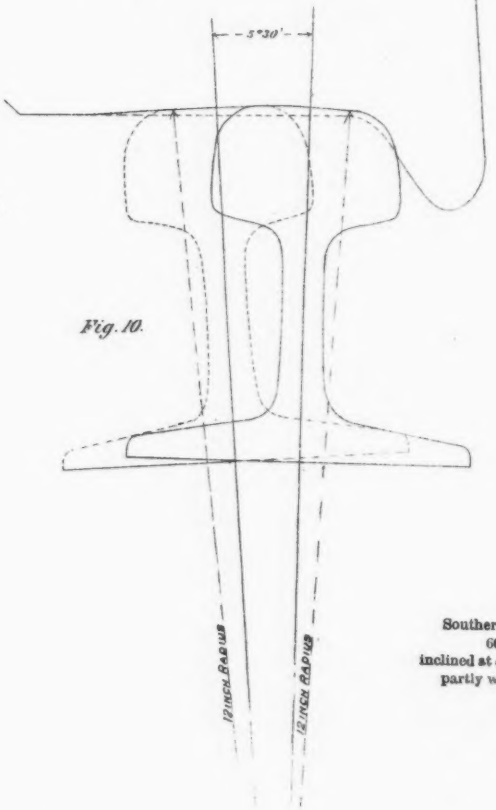


Fig. 10.

Worn "Blind" (Flangeless) Driving Wheel
Tire 10 Wheel Engine. S. P. Co.

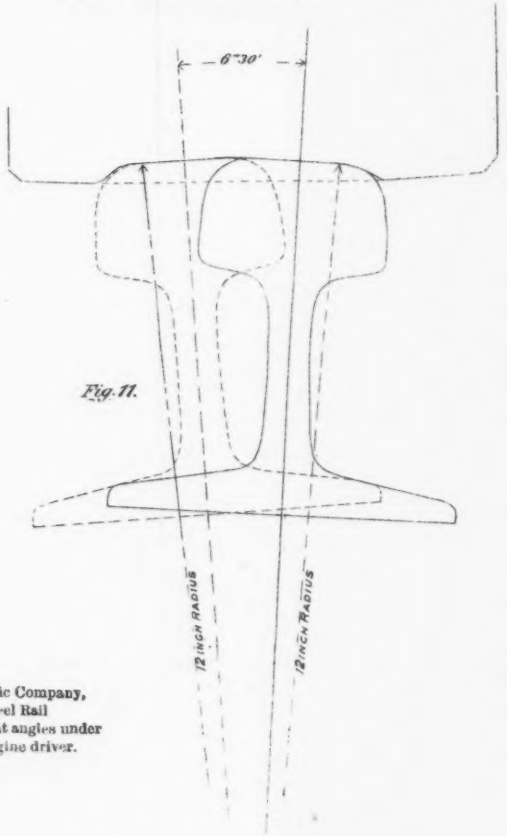
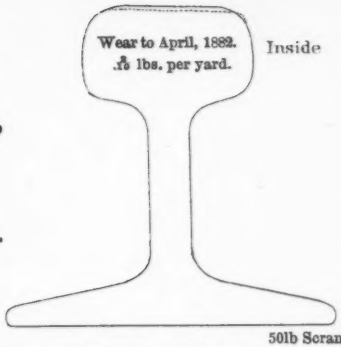


Fig. 11.

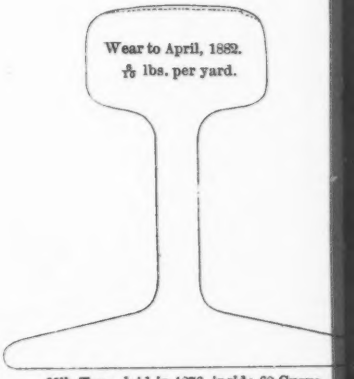
Southern Pacific Company,
60 lb. Steel Rail
inclined at different angles under
partly worn engine driver.

Half Size Sections of Worn Rails in Track, near Colfax, Measured April, 1882. Sacramento Div. Central Pacific R. R.



501b Scranton, laid
Inside 6° Curve, Sta. 2892.

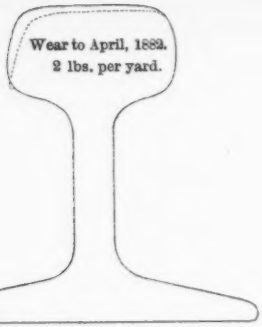
601b Troy, laid in March, 1876.
Outside 6° Curve, Sta. 2798, Curve, up to Sept. 1881, had ¼" Elev. pr Deg.



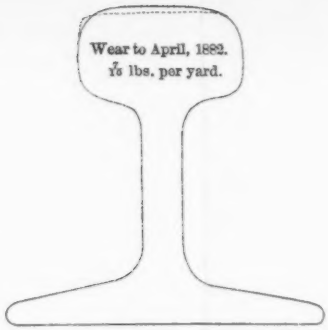
601b Troy, laid in 1876, inside 6° Curve, Sta. 2798.

601b Cambria
Outside 7° Curve, Sta. 2994.

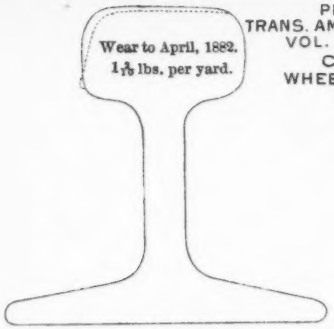
Inside



501b Scranton, laid Oct., 1877.
Outside 6° Curve, Sta, 2892.

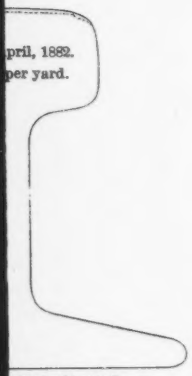


501b Scranton, laid Oct., 1877.
Inside 3° Curve, Sta. 2881.

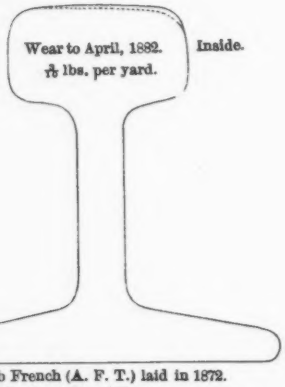


Outside 3° Curve, Sta. 2881.

pril, 1882.
per yard.



1876, inside 6° Curve,



601b French (A. F. T.) laid in 1872.
On Tangent, Sta. 2967.

601b French, laid in 1872. Outside 10° Curve
Sta. 2930.

(A. F. T.)
601b French, made in 1871, laid in 1872
Inside 10° Curve, Sta. 2930.

601b Cambria. laid in 1874.
7° Curve, Sta. 2994. Inside 7° Curve, Sta. 2974.

501b Scranton, laid Oct., 1877.
On Tangent, Sta. 2835.

Inside.

601b French (A. F. T.) laid in 1872.
Inside 8° Curve, Sta. 2975.

SOUTHERN PACIFIC COMPANY.—SERVICE OF ALL NEW NUMBERED 33-INCH GROUND CAST-IRON CAR WHEELS FOR FOUR YEARS, ENDING APRIL 30TH, 1885.

		TOTAL MILEAGE.	AVERAGE MILEAGE.	
Total number in service	4 114			
Passenger wheels condemned	1 012	56 503 248		
Freight wheels condemned	41	1 762 760		
Total wheels condemned	1 053	58 266 008	55 333	
Cost per wheel				$8.72
Cost per mile				.00013
Of wheels condemned, 356 or 34 per cent. sharp		20 744 693	58 272	
Of wheels condemned, 144 or 13 per cent. worn out		9 366 190	65 043	
Of wheels condemned, 553 or 53 per cent. other causes		28 155 125	50 913	
WHEELS IN PASSENGER SERVICE.				
Of wheels condemned,	343 or 34 per cent. sharp	19 994 521	58 293	
Of wheels condemned,	142 or 14 per cent worn out	9 335 564	65 743	
Of wheels condemned,	527 or 52 per cent. other causes	27 173 163	51 562	
Total wheels condemned, 1 012		56 503 248	55 833	
Cost per wheel				$8.72
Cost per mile				.00016
WHEELS IN FREIGHT SERVICE.				
Of wheels condemned,	13 or 32 per cent. sharp	750 172	57 706	
Of wheels condemned,	2 or 5 per cent. worn out	30 626	15 313	
Of wheels condemned,	26 or 63 per cent. other causes	981 962	37 767	
Total wheels condemned, 41		1 762 760	42 994	
Cost per wheel				$8.72
Cost per mile				.00020

SOUTHERN PACIFIC COMPANY.—SERVICE OF ALL NEW NUMBERED GROUND AND UNGROUND 33-INCH CAST-IRON CAR WHEELS FOR FOUR YEARS ENDING APRIL 30TH, 1885.

		TOTAL MILEAGE.	AVERAGE MILEAGE.	
Total number in service	33 228			
Passenger wheels condemned	3 433	200 991 211		
Freight wheels condemned	2 754	58 137 028		
Total wheels condemned	6 187	259 128 239	41 883	
Cost per wheel				$8.54
Cost per mile				.000204
Of wheels condemned, 1 144 or 18 per cent. sharp		71 280 087	62 308	
Of wheels condemned, 492 or 8 per cent. worn out		32 896 907	66 865	
Of wheels condemned, 4 551 or 74 per cent. other causes		154 951 245	34 047	
WHEELS IN PASSENGER SERVICE.				
Of wheels condemned, 1 039 or 30 per cent. sharp		66 311 981	63 823	
Of wheels condemned, 387 or 11 per cent. worn out		27 942 379	72 203	
Of wheels condemned, 2 007 or 59 per cent. other causes		106 736 851	53 182	
Total wheels condemned, 3 433		200 991 211	58 547	
Cost per wheel				$8.54
Cost per mile				.000146
WHEELS IN FREIGHT SERVICE.				
Of wheels condemned, 105 or 4 per cent. sharp		4 968 106	47 315	
Of wheels condemned, 105 or 4 per cent. worn out		4 954 528	47 186	
Of wheels condemned, 2 544 or 92 per cent. other causes		48 214 394	18 952	
Total wheels condemned, 2 754		58 137 028	21 110	
Cost per wheel				$8.54
Cost per mile				.000405

SOUTHERN PACIFIC COMPANY.—SERVICE OF ALL OLD NUMBERED GROUND 33-INCH CAST-IRON CAR WHEELS FOR FOUR YEARS ENDING APRIL 30TH, 1885.

		TOTAL MILEAGE.	AVERAGE MILEAGE.	
Total number in service	5 136			
Passenger wheels condemned	361	13 870 159		
Freight wheels condemned	1 749	31 388 377		
Total wheels condemned	2 110	45 258 536	21 450	
Cost per wheel				$4.72
Cost per mile				.00022
Of wheels condemned, 188 or 9 per cent. sharp		6 503 538	34 593	
Of wheels condemned, 128 or 6 per cent. worn out		3 832 441	29 941	
Of whee's condemned, 1 794 or 85 per cent. other causes.		34 922 557	19 466	
WHEELS IN PASSENGER SERVICE.				
Of wheels condemned, 63 or 17 per cent. sharp		2 777 447	44 086	
Of wheels condemned, 47 or 13 per cent. worn out		1 749 656	37 227	
Of wheels condemned, 251 or 70 per cent. other causes		9 343 056	37 223	
Total wheels condemned, 361		13 870 159	38 421	
Cost per wheel				$4.72
Cost per mile				.00012
WHEELS IN FREIGHT SERVICE.				
Of wheels condemned, 125 or 7 per cent. sharp		3 726 091	29 809	
Of wheels condemned, 81 or 5 per cent. worn out		2 082 785	25 713	
Of wheels condemned, 1 543 or 88 per cent. other causes		25 579 501	16 577	
Total wheels condemned, 1 749		31 388 377	17 946	
Cost per wheel				$4.72
Cost per mile				.00026

SOUTHERN PACIFIC COMPANY.—SERVICE OF ALL NUMBERED 33-INCH CAST-IRON CAR WHEELS FOR FOUR YEARS ENDING APRIL 30TH, 1885.

		TOTAL MILEAGE.	AVERAGE MILEAGE.	
Total number in service	38 364			
Passenger wheels condemned	3 794	214 851 370		
Freight wheels condemned	4 503	89 525 396		
Total wheels condemned	8 297	304 376 766	36 685	
Cost per wheel				$7.57
Cost per mile				.00020
Of wheels condemned, 1 332 or 16 per cent, sharp		77 783 625	58 396	
Of wheels condemned, 620 or 8 per cent. worn out		36 729 348	59 241	
Of wheels condemned, 6 345 or 76 per cent. other causes		189 863 793	29 954	
WHEELS IN PASSENGER SERVICE.				
Of wheels condemned, 1 102 or 29 per cent. sharp		69 089 428	62 695	
Of wheels condemned, 434 or 11 per cent. worn out		29 692 035	68 415	
Of wheels condemned, 2 258 or 60 per cent. other causes		116 069 908	51 403	
Total wheels condemned,	3 794	214 851 371	56 629	
Cost per wheel				$7.57
Cost per mile				.00013
WHEELS IN FREIGHT SERVICE.				
Of wheels condemned, 230 or 5 per cent, sharp		8 694 197	37 801	
Of wheels condemned, 186 or 4 per cent. worn out		7 037 313	37 835	
Of wheels condemned, 4 087 or 91 per cent. other causes		73 793 895	18 055	
Total wheels condemned,	4 503	89 525 405	19 881	
Cost per wheel				$7.57
Cost per mile				.00038

SOUTHERN PACIFIC COMPANY.—33-INCH CAST-IRON CAR WHEELS. SERVICE OF ALL NUMBERED WHEELS FOR SEVEN YEARS ENDING APRIL 30TH, 1888.

NEW WHEELS, NOT GROUND.

Total number put in service			45 800
Total number condemned			11 834
Of the number condemned,	1 573	were sharp, or	13 per cent.
Of the number condemned,	1 194	were worn out, or	10 per cent.
Of the number condemned,	9 067	were on account of other causes, or	77 per cent.
Total number condemned,	11 834		

NEW WHEELS GROUND.

Total number put in service			12 750
Total number condemned			2 793
Of the number condemned,	637	were sharp, or	23 per cent.
Of the number condemned,	447	were worn out, or	16 per cent.
Of the number condemned,	1 709	were account of other causes, or	61 per cent.
Total number condemned,	2 793		

OLD WHEELS GROUND.

Total number put in service			5 700
Total number condemned			2 901
Of the number condemned,	295	were sharp, or	10 per cent.
Of the number condemned,	208	were worn out, or	7 per cent.
Of the number condemned,	2 398	were account of other causes, or	83 per cent.
Total number condemned,	2 901		

FREDERIC A. DELANO, Chicago, Burlington and Quincy Railroad.—I inclose herewith a brief paper on the subject of rail sections, which gives perhaps as concisely as possible the views I have arrived at on a subject which I have studied to the exclusion of everything else for over a year and a half.

I also send you an engraving of a rail section, Fig. 11, designed by me last October for an 85-pound rail, which combines to the fullest extent I was able the qualities which I deemed essential to a good wearing rail.

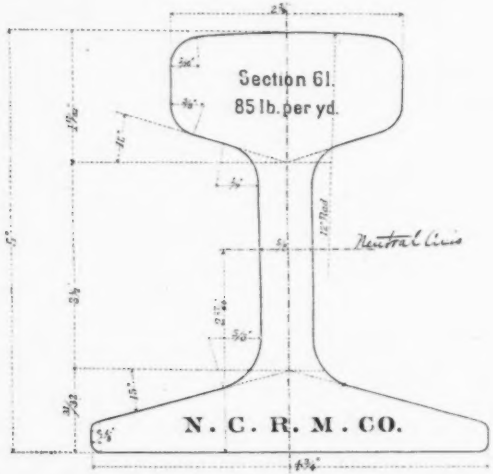


FIG. 11.

In considering the question of rail sections, I have thought that it was not simply a question of mathematics and applied mechanics, but one in which the metallurgy of steel and the usual methods of manufacture play an important part. I am most strongly opposed to the type of section illustrated by your Fig. 2 of the standard for the Lehigh Valley, and of course even more so to the Cumberland Valley section, Fig. 3, and while I like in the main Mr. Hawks' design for the Michigan Central, I am still inclined to think it can be improved on.

I adopted in my section a 12-inch top radius, and five-sixteenths corner radii, as I found that rails on our road usually wore to practically that shape on tangents.

I approve the vertical sides too of Mr. Hawks' design, but I think his corner fillets on the edge of the flange possibly a little too small.

In regard to the breadth of head, I have gone, as you will see, a little further than Mr. Hawks.

I agree entirely with the conclusions of the Committee on the subjects alluded to in the first five questions of the circular of March 18. They are practically exactly the conclusions which I came to after very careful study of the rails on some 500 miles of main line on the Chicago, Burlington and Quincy Railroad. In other words, I think that as the wheel can roll only on one diameter, the corner radius of the rail head and the fillet radius of the wheel should be as dissimilar as possible.

In regard to the proposition of a flat rail top for a cylindrical wheel advised by Mr. Whittemore, I do not find it so easy to come to a decision. Mr. Whittemore's paper suggests a very interesting problem. From the consumer's standpoint, there is only one way in which a flat topped rail can be properly rolled, and that is by making the rail unsymmetrical, as shown in the sketch inclosed, Fig. 12, but I am in doubt whether the difference between a curve of 12-inch radius and a curve

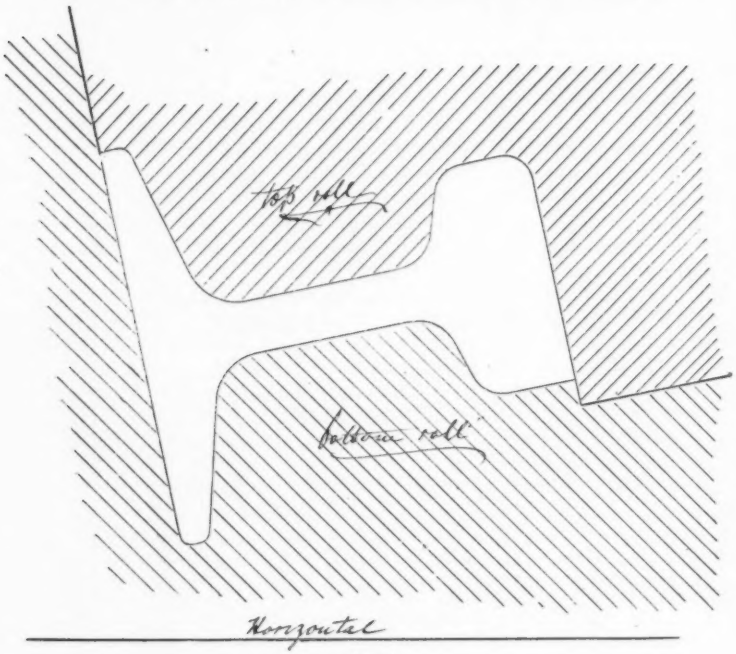


FIG. 12.

which the rail head would assume, even though it started flat, is sufficient to be of very great importance. I do not agree with Mr. Whittemore at all in the idea that the split heads have been produced by the curve

top of the rails, and I inclose etching prints, Plate LXXIII, from several pieces of 56-pound rail, which had never been in track. These pieces, as labeled, came from a single rail of some 150 feet length, rolled from one ingot, and show very well, I think, that the split in the rail head is probably due to an incipient crack which probably exists in some 15 or 20 per cent. of all the rails in track. I also inclose two other etching prints from rail ends near the top and near the bottom respectively of another ingot, which confirms the information of the other prints. (Plate LXXIII, Figs. 6 and 7.) The recent criticism made by Mr. Sandberg that the flat top rail could never be laid in the track absolutely correctly so as to have the tire bear on all parts of the flat surface, is a very just one, and the only theoretical difference I can see between the wear of an absolutely flat top rail and a rail as flat as a 12-inch radius, is, that in one case the flat top rail would be worn on each side of the center by the wheels, which are necessarily slightly hollowed, while in the other case the crown of the rail head would be worn down until it assumed the shape of the average wheel. With rails of so many different widths of head, and with the different track gauges in use and the differences in wheel gauge, there is a considerable play for the wheel on the rail, and so long as this exists the wheel is bound to be hollowed, though in this hollow there may be a flat cylindrical surface of as much as 1½ inches in width. I agree entirely with Mr. Whittemore that the wheels should be cylindrical and not coned in the slightest degree, and I hope that the Master Car Builders' standard will soon be modified in this respect, and at the same time increase the throat fillet to ¾ of an inch radius.

Before closing, I must ask your pardon for treating in too hurried a manner so important a subject. It is one in which I am very much interested, and on which I have spent, first and last, a good deal of time. On account of pressure of other work, I cannot devote to this as much time as I should like, and I am obliged to send you this too hasty letter, which sounds, I confess, a little egotistical, or else remain silent.

The following are extracts from the paper above referred to.*

"The designing of many rail-sections by engineers who are far from being experts in the metallurgy of steel has led to the general acceptance of erroneous principles as the rules for such designs. Until very recently it has been assumed that the more metal there was put in the head, to wear away, the longer the rail would wear; and it has been the practice, in adopting heavier sections, to put all the additional weight on top of the rail-head of a very much lighter section. Careful investigation on a number of railroads has shown that of the rails weighing 65 pounds per yard and over, the greater part have to be removed after comparatively trifling abrasion, solely because they are no longer fit for a smooth track. This is evidence of error in the principles of the design of the section.

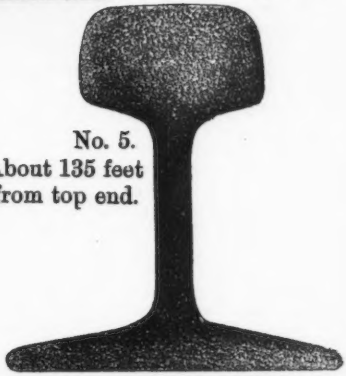
* Rail Sections, by Frederic A. Delano, Trans. Am. Inst. Mining Engineers, Vol. XVII.

No. 1.
About 5 feet
from top end.

No. 3.
About 70 feet
from top end.

No. 2.
About 37 feet
from top end.

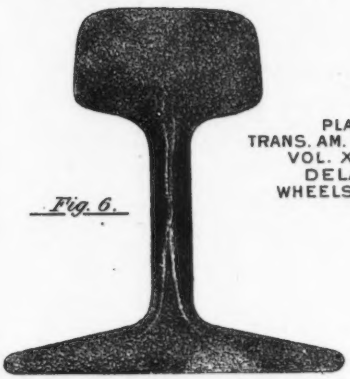
No. 4.
About 102 feet
from top end.



No. 5.
About 135 feet
from top end.

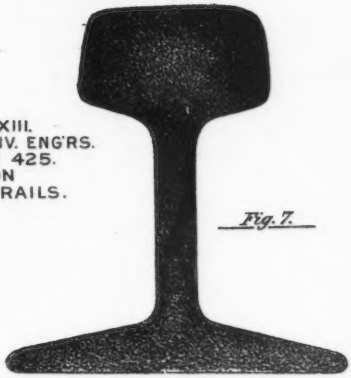
PLATE LXXIII.
TRANS. AM. SOC. CIV. ENG'RS.
VOL. XXI. Nº 425.
DELANO ON
WHEELS AND RAILS.

Fig. 6.



From near the top

Fig. 7.



From near the bottom

of the same ingot.

"It is generally admitted that, as a rule, rail-sections designed since 1879, for rails of 65 pounds and over, have not given entire satisfaction. There are several reasons which may account for this: first, a constant increase, during this period, of wheel-loads on engines and cars, together with generally higher speeds; secondly, new methods in manufacture, cheapening the cost of production and possibly producing an inferior article; thirdly, mechanical conditions in the rail itself, due to the shape of the rail-section.

"1. The first cause is undoubtedly a real one. I think there is evidence that the elastic limit of much of the rail-steel now in use is often actually exceeded by the strains of practice, causing a flow of metal, which is then abraded by the wheel flanges. Granting the existence of this cause, there are two ways of ameliorating the result; one is to increase the bearing-surface of wheels on rails; the other, to raise the elastic limit of the metal.

"2. With regard to the second cause, it is held by many that the enormous production, low cost, and 'improvements' induced by competition have involved inferior quality of product. Many well-informed men are content to rest on the simple assertion that the old John Brown steel gave remarkable satisfaction, because it was made of good iron and did not contain more than .08 per cent. of phosphorus, any analysis showing more being grossly inaccurate. Low phosphorus steel can be made to-day with more certainty and at less cost than ever before. The only question is, whether the elimination of phosphorus is going to be worth what it costs. The fact that as many Bessemer charges are now blown in one hour as were formerly blown in a day, is pointed at as evidence that the same care cannot be given to the operation; but I think men really conversant with the turning-out of a large product will maintain that almost absolute uniformity in the iron is necessary to keep things running with the clock-work regularity required for such a rate of production. Indeed, large product and general smoothness in mill-operation are, to my mind, an indication of a uniform product, so far as metal in the rail itself is concerned, and seem to me, therefore, not objectionable on that score. With the rapid rolling, however, particularly the rapid blooming or breaking-down of large ingots, I find fault, as I have explained at some length in my former paper, already cited.

"3. That mechanical conditions in the rail itself, due to the general design of the rail section, can have any important effect on the service-value of rails has not been generally admitted, so I wish to lay particular stress upon this cause and attract to it the recognition it deserves. Speaking in general terms, that form of rail is, in my opinion, faulty, which has a deep massive head, a wide, thin base and a thin web, connected to the head and the base by small fillets only. The objection to this form and the advantages which might be obtained by different proportions may be concisely enumerated as follows:

"*a.* Such a form necessitates rolling at a higher temperature, and, what is of chief importance, finishing at a higher temperature than permits the securing of a well-forged, compact rail.

"*b.* This type of section probably encourages the use of a higher percentage of manganese to reduce the number of second-quality rails; and this production of second quality rails, as well as the additional manganese, figure in the cost of the rails to the consumer.

"*c.* Rails with heads out of proportion to the rest of the section require a great deal more cold-straightening, because it is impossible to

know how much bending or cambering such a rail needs in its hot state in order that it shall cool straight. This is certainly a very important consideration.

"*d.* The same sort of disproportion must produce corresponding disproportions in the rate of cooling, causing internal strains which are only partly dispersed or effaced by the small connecting fillets.

"*e.* A section having these internal strains exaggerates the effect of any impurity which may chance to have segregated in the ingot, while a section not liable to these strains would safely admit of a generally higher carbon steel as well as a considerable latitude in composition.

"*f.* It is not economical to provide for an abrasion of some ⅜ of an inch, or even more, from the top of the rail, if it is found that rails generally fail long before this amount has been abraded. Instead of providing more height to wear away we can do better by providing more breadth of bearing-surface, and metal of a higher resistance within the elastic limit.

"*g.* Inasmuch as the funnel-shaped cavity, dispersed blowholes and possible impurities exist in the ingot in the axis of its length, it follows that these defects will exist (especially in rails made from the upper part of the ingot) on an axial line which passes through the rail-section. It follows that if the rail-section has 50 to 55 per cent. of its metal in the head, the poorest metal is inclosed in the head, where it receives the least amount of forging; whereas, if the amount of metal in the head does not exceed 40 to 45 per cent., this poor metal occurs in the thoroughly-worked web portions.

"It seems to me that rail-sections should be made to certain definite proportions, regardless of the weight per yard. It is often said that the larger sections will admit the use of a higher carbon-steel; but this assertion requires the proviso that the heavier section shall be similarly proportioned. One 74-pound section which I have in mind could not be safely made of as high a carbon steel as the 62-pound section from which it has been schemed.

"While I am deeply interested in the recently published researches of Mr. D. J. Whittemore, Chief Engineer of the Chicago, Milwaukee and St. Paul Railroad, and agree entirely with him in his conclusions that wheels should be cylindrical and the bearing surface should be increased, it seems to me that a rail head of 12 inches radius is flat enough. Since there is a lateral play of fully ½ an inch for the average car-wheel on an average track (not to mention a 4 foot 9 inch gauge) both the wheel treads and the rail heads must wear to a curve. On the other hand, if the rail head begins with a slight top-curve, it would take no longer than with the flat topped rail to assume the curve of the average wheel.

"The problem is to increase the life of rails without greatly enhancing the cost. It might be possible to make a 60-pound rail of steel worth $75 per ton give as good service as an 85 pound rail made of $30 steel; but the discovery would not prove remunerative.

"With regard to internal fillets and flat fishing angles, I have held the extreme view, that the fillets should be liberal and the angles of enough slope (certainly not less than 15 degrees), to allow really colder rolling than is anywhere the practice in this country."

P. H. DUDLEY, Engineer of Tests, New York Central and Hudson River Railroad.—The broad assumption in the conclusion of the Committee as to causes of sharp flanges is not warranted from the evidence submitted.

Switching engines of the four wheel type without trucks to guide them and having the usual flange play usually wear the flanges of all the drivers. Reduce the amount of flange play to ¼ of an inch and the flange wear of the drivers is nearly checked. This was shown by lessening the flange play of the drivers of the switching engines in the Grand Central Yard previous to the year 1876, and it has since been continued. The flange play on the engines of the New York Central has also been lessened, the flange wear being decreased.

The majority of drivers of passenger locomotives, with proper leading trucks, do not wear the flanges of the driving wheels sharp. Freight car trucks with short wheel bases and large flange play, have a much larger percentage of sharp flanges than passenger coaches with longer wheel bases.

The flange play of ¾ of an inch and about ½ of an inch of journal play, is too much for a freight car truck, as it permits the outside leading wheel flange of the truck to impinge on the rail forward of a perpendicular from the center of the wheel, and abrasion of wheel and rail takes place; the ratio increasing as the gauge widens by wear of wheel and rail.

The axles, instead of running parallel to the radius of the curve, point forward of its center.

If the wheel runs normal to the curve, the abrasion is slight and the lines can only be traced on the side of the head of the rail; if the short wheel base and flange play permit a large angle, the abrasion is faster, the lines become more distinct.

On an outside rail on a sharp curve on a heavy down grade, the abrasion is very severe and rapid, over $\frac{5}{16}$ of an inch being worn away from the side of the head of rail in nine months' service, the tonnage passing over the rail being 4 350 000 tons.

The experience with perfect wheels, if any exist, is very limited. Under my own car, wheels with perfectly cylindrical treads of exactly the same diameter upon the same axle, in a four wheel truck, 7-foot wheel base, have run over 100 000 miles without showing any tendency to sharp flanges.

In the six wheel truck, 11-foot wheel base, the two outside pairs of wheels have only ¼ of an inch play between the flanges and rails; these have run 70 000 miles, the flanges are worn but are not sharp. The limited amount of play in this long truck was not to prevent flange wear but to check the oscillations of the truck.

Flange wear causes train resistance, consequently increased coal consumption.

Flat top rails were the first used by many American roads: Boston and Lowell Railroad, Western Massachusetts Railroad, Reading Railroad and Cleveland and Erie Railroad, and the inverted U rail of the Baltimore and Ohio Railroad; something similar to the type of

rail with two legs as suggested by Mr. Whittemore. Of most of those sections I have seen rails which have been in service, and all were worn rounding on the head. It was then deemed advisable by the civil engineers and rail makers to make subsequent rails with the curve on top when new. The radius has been made much too short, 6 inches being very common, until within a short time. Experience has shown that it is advisable to lengthen the radius and at the same time broaden the head of the rail to give greater bearing surfaces to both wheel and rail. With the worn wheels which must pass over these rails, experience shows on the broad head that it will be some time before the curve will be worn much longer than 12 inches radius; after more of these broad headed rails are in the tracks, the wheels will be worn to a larger curve, and then the rail can be made with a longer radius for the curve on the head of the rail.

WILLIAM FORSYTH, Mechanical Engineer, Chicago, Burlington and Quincy Railroad.—I agree to the preliminary conclusions relating to wheel wear, page 28; items 2, 3 and 4, but not to 1. No. 5 applies to chilled wheels, not steel tires. The two kinds of wheels should be considered separately. Soft tires will wear sharp flanges and have a short life.

In regard to rail wear, I inclose a letter from Mr. E. W. Penfield, who has charge of our rail records, and I give you his opinion on this subject in preference to my own.

CHICAGO, May 1st, 1889.

WILLIAM FORSYTH, ESQ., *Mechanical Engineer:*

DEAR SIR,—Referring to the circular sent out by the American Society of Civil Engineers, March 18th, which you forwarded to me some time since, I would say that in the main the opinions set forth in the Committee's preliminary report are confirmed by my experience.

I inclose two different rail sections, Figs. 13 and 14, taken from track after over seven and one-half years' wear and 30 000 000 tons service, in which you will notice that $\frac{5}{16}$ inches upper corner radius is a trifle nearer the line than $\frac{1}{4}$ inch radius.

The vertical sides of the head, I have, as you know, advocated for a long time. I do not like the small lower corner radius, except when a splice bar is to be used, which latter I do not think is the best form of joint. We should not deform the rail to accommodate the joint.

The depth of the Michigan Central rail head is 60 per cent. of the width. If the width was increased so that the percentage should be 55, the head would be improved.

The $\frac{1}{4}$ inch fillets from the web to the base and head are radically wrong.

In order to avoid as much as possible internal strains in the metal in the different parts, these fillets should be as large as practicable, say of ½-inch radius when a splice bar is to be used, or ⅜-inch radius where

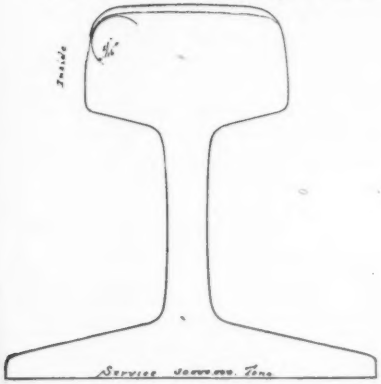


FIG. 13.

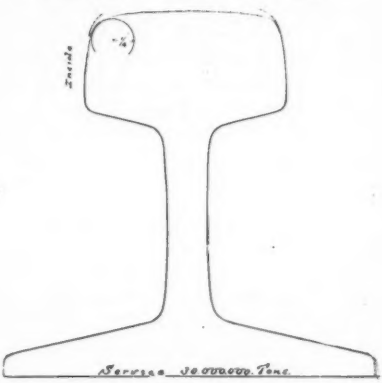
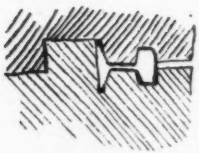


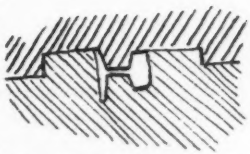
FIG. 14.

some form of under joint is adopted. In which latter case also the upper fishing angle might be materially increased with advantage.

I do not agree with Mr. Whittemore concerning the flat top for the rail, for the following reasons: The tread of the wheel always wears in a curve, on account of the truck shifting from one side to the other of the track. The longer the service the more concave this curve. As soon as the tread commences to get hollow, the bearing on a flat topped rail would be necessarily on one or the other (or both) of the upper corners and not at all in the middle, and the rail soon has a slight top curvature. With our present system of rolling, the rolls are divided in the middle of the head, as per sketch, and it would be difficult to have the metal fill out the section were it not for this slight curve on the top.



The only means of avoiding this is by dividing the rolls at the top the same as at the bottom, thus:



which would make a one-sided rail, one of the upper corners being square. This would cause extra expense in laying. Also, I think a 12-inch radius is quite as good as a flat top.

Now that the subject of upper corner radius has been acted upon, I hope that before long the fillet radius of the wheel flange will be changed back to ¾ inch, and thus get all the possible benefit from what some have long thought to be the better lines for adoption.

Yours truly, EDWARD W. PENFIELD.

Mr. GEORGE GIBBS, Mechanical Engineer (Chicago, Milwaukee and St. Paul Railroad), states, in addition to his recorded responses to questions of circular, that he considers that the number of sharp flanges is considerably influenced by the contour of wheel tread and also rail head.

He considers cylindrical wheels undesirable on account of tendency to flange wear, and absolute flat tops to rails as aggravating this tendency and also defeating the object sought, of increasing contact area from causes of imperfect surfacing of track. Say, 12-inch radius to rail top and same to main portion of wheel tread he believes will provide the desired contact under practical working conditions; attention being given to radii of fillet to prevent flange wear as noted.

MILTON G. HOWE, M. Am. Soc. C. E.—My opinion is that the life of both wheels and rails would be prolonged if the rails were made flat on top and the tread of wheels cylindrical. The load and wear would be distributed over the entire width of rail head instead of a part of it. This condition, under the present system, is only reached when the head of the wheel is worn hollow to approximately fit the convex top of rail. In the meantime there is evidently unnecessary wear, which is objectionable.

J. D. HAWKS, M. Am. Soc. C. E.—The Michigan Central section for 80-pound rail embodies my idea as to correct rail section. Since that section was published I have seen a number of sections for different railroads practically like it, and inclose you blue print of a couple received to-day from Colonel W. R. Jones, of Carnegie Bros.*

It will be seen from the sections that the small lower corner radius is not objected to by the mill people, as Colonel Jones uses a radius of $\frac{1}{8}$ of an inch, instead of three thirty-seconds, as in the Michigan Central rail. I inclose plan (Fig. 15) showing section of old Canada Southern 60-pound rail, and also, in dotted lines, section of a rail I found in the scrap pile the other day. Of course it cannot be expected that we shall be able to get any such wear from all our rails. This particular rail was sound from end to end, and no more worn at the joint than elsewhere. The broad head idea, however, may be carried too far in this climate.

Fig. 16 shows sections of an old Michigan Central iron rail that made trouble in winter by reason of wet snow packing on the head of rail and lifting locomotive truck wheels off the track.

I see no advantage in making the rail top flat. The wheels, having play, would soon round it to about 12-inch radius. The track of a wheel is an irregular line along the rail top, unless some portion of the top is noticeably higher than the rest. This may happen by rail coming from rolls a little full on top (which is not objectionable if not too

* These are included in the illustrations of the discussion by Mr. W. R. Jones, immediately following this discussion. (Plate LXXIV.)—ED.

much so), or by rail being laid brand side in when brand side should be laid out, or by changing rail from one side of the curve to the other. In such cases it takes some little time to wear rail, so top will wear bright the full width, but nothing like splitting of the rail follows ; in

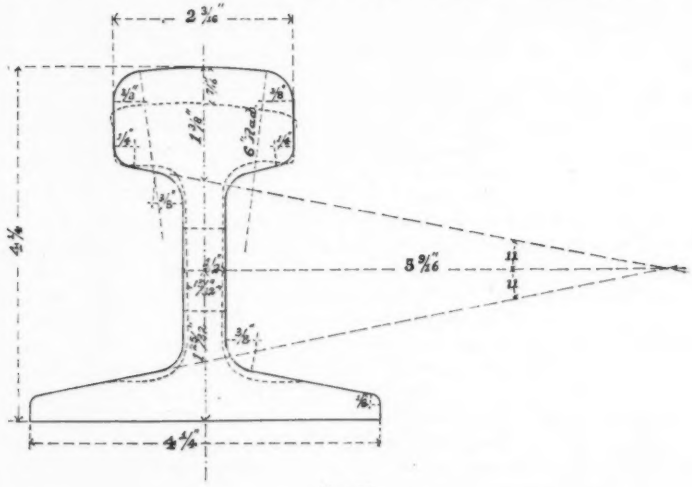


FIG. 15.

fact I have never seen a sound steel rail split in a main track proper. We can split rails for a trifling distance from the end in stub switches when space at end of rail is great, or on our ferry boats where there is something of a jump from the table to the boat, but only then after long hammering.

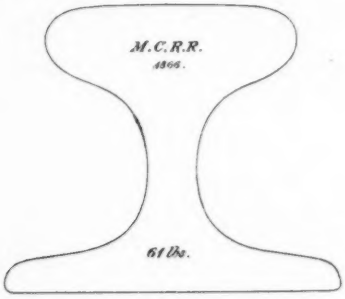


FIG. 16.

I was on the Lake Shore and Michigan Southern, when that road laid its first steel rail, and have paid particular attention to the rail

question from that day to this, and with the same conditions before me, as mentioned by Mr. Whittemore, I draw an entirely different conclusion. A faulty ingot may produce a rail that will not show a defect for years. but the defect is there, and when the rail is sufficiently worn or unusually strained the defect will show.

I probably have had as much trouble with soft rails as any one, but can say that with the softest of the "pewter rails," the ends did not split even when mashed down a ¼-inch. It was a very serious matter when rails were giving out inside of a year with reasonable usage by reason of being too soft, but our trouble from that source is happily ended. We have been using the long six hole angle splice for five years, and during that time have not taken out a rail because of battered end when the long splice was used.

Breaking at the bolt holes is also a thing of the past with joints laid with the long splice, and split rails are now few and far between as compared to ten years ago. I believe there is no more theory about track work than about medicine, and so do not claim the above facts prove that the long splice is entitled to the whole credit for the different behavior of rails during the past five years. I think the splice has something to do with it, but believe the rail men are making better rails.

Some years ago I was led astray by the theory that a wheel should fit the rail, and so fitting would lessen the number of sharp flanges. I first discovered there must be something wrong with the theory when I found sharp flanges only on one of the wheels on an axle, never on both. I then had holes cut in the floor of my car over the wheels and window glass fitted to them to keep out dust, and spent many hours watching the action of wheels on the rails, and my conclusion is that the ½-inch radius for top corner of rails will not hurt the wheels and will give us a considerable addition to the "precious metal," on the rail top, also that the rail wears much faster after it fits the wheel than before.

WILLIAM R. JONES, General Superintendent Edgar Thomson Steel Works.—I pass over the first six interrogations of the circular and the one marked "A," and consider the questions as being strictly in the province of railroad officials.

From the manufacturers' standpoint, I would urge that the 12-inch top radius be adopted. It is a difficult matter to roll flat heads and get smooth surface, and also a difficult matter to maintain a reasonable height in section of rail. The standard practice in mills is when new rolls are prepared to have height of rail $\frac{1}{64}$ of an inch less than templet, and when rolls are dressed in order to insure smooth heads the height of section is gradually increased, and the limits in height of section from a set of rolls is represented, at first by section being $\frac{1}{64}$ of an inch low, and the ultimate height $\frac{1}{32}$ of an inch higher than templet. With the 12-inch radius as rolls are dressed, and as each dressing will represent a reduction of $\frac{1}{4}$ of an inch in diameter, that part of the roll forming top of head

must be turned smooth, and the 12-inch radius in the top of head helps to compensate for metal turned off rolls, in dressing. I append drawing, Plate LXXIV, showing the section of rail in the pass before the finishing pass, which is technically termed the leading pass, and also of the finishing pass.

A is the section of rail in leading pass.
B section of rail in finishing pass.
C is cold or finished section.

I give the figures in width of flanges and height of rail, to show the allowance we make in finishing pass for shrinkage. You will notice that the head of rail in *A* has a decided bevel. This is done so that as rolls are reduced in diameter we can smooth that part of the roll that forms the head which is so essential to get smooth rails. As a maker of rails I would strongly urge the adoption of the 12-inch radius.

The question of vertical sides is a debatable one. I would say to those roads where tangents are the rule and curves the exception and of great radii that straight sides are admissible, but on roads where curves are the rule, and tangents almost unknown, then sides of heads would better be made with at least a 4-degree angle. Drawings *D* and *E*, Plate LXXIV, of rails in Pennsylvania Railroad track, on the Brinton curve, show the form of head assumed by wear of rail.

The small lower corner radius is essential, in order to get all the bearing possible for fish-bars. The addition of metal by reason of small radius in corner is an infinitesimal percentage in weight of rail, but is a large percentage in bearing surface for fish-bars. As a rule, the fish-bar's bearing on the under side of head has been totally inadequate, and fish-bars have been of the most trifling character, considering the important relation they bear in maintaining a good roadway.

The broad, shallow head I consider a decided step in the right direction. The mistake of the past has been in massing metal in vertical section of head. The testimony is that the original 60-pound section, Pennsylvania Railroad standard, has worn far better than the 67-pound section of the same road. I receive the same testimony from other railway officials who have used the two sections. I also append drawings *F* and *G*, Plate LXXIV, showing the difference in metal in head of the two sections.

It is a fixed rule in mechanics that, where we find any part of machinery that wears too fast, we endeavor to remedy the evil by increasing the wearing surface.

One of the greatest evils we have to contend with in rolling rails is the unequal distribution of metal, requiring the rails to be curved when hot to allow for shrinkage, owing to the mass of metal in the head and the sometimes wonderfully thin flanges and webs.

I would remark that, when wonderful records of rails are poured into the manufacturer's ears, the sections of such rails do not show deep

heads, thin webs and thin flanges, but on the contrary they represent rails where the metal was well and equally distributed. In connection with this subject, I was informed by Mr. Gunn, Engineer of the Kentucky Union Railway Company, that rails that this Company had furnished to the Cincinnati Southern Railway Company had been removed from the track not because the head had worn out, but because the flanges had worn out, and became so thin that the rails were too weak for safety. Here is, to me at least, a new development.

I append drawing *H*, Plate LXXIV, showing a section of rail taken out of track of Baltimore and Potomac Railroad for the same reason, which shows the wear on flanges. I have prepared for Mr. Richards, Assistant Chief Engineer, Pennsylvania Railroad, two designs of 85-pound sections and two designs of 90-pound sections,* Figs. *J*, *K*, *L*, *M*, Plate LXXIV. It will be observed that I have a broad, comparatively shallow head, good wide, heavy flanges and strong webs. These large sections admit of this. The edges of flanges are square, with slight radii on corners. The object of square edge of flanges is to give the best attainable contact surface for spikes. The rounded edges soon wear into spikes, thus allowing rails to spread the amount represented by wear in flanges and spikes. This form of flange will reduce this evil to the minimum.

I do sincerely hope that your Society may be able to formulate a series of standard sections and recommend their adoption. It will secure better work at the mills, for where now, owing to the many and wonderfully and fearfully constructed sections, we are compelled to keep a ten-acre lot full of rolls, we could afford to keep duplicate rolls, or even triplicate rolls of each standard section. Then mills could afford to carry a stock of standard rails subject to immediate shipment when necessary.

Pardon me for speaking on one important subject: The rolling of steel at the lowest possible temperature has many warm advocates. Conceding that many mills roll too hot, yet it must be borne in mind that there are six mills which now roll rails at the lowest heat possible.

WALTER KATTÉ, M. Am. Soc. C. E.—I am not inclined to admit the conclusion that the tendency to "sharp flange" is a natural phenomenon existing in all perfectly running wheels, but am rather of the opinion that it results very largely from some imperfection in the wheels themselves; probably to a very large extent, wheels out of true circle, not regular in the profile contour of their flanges and treads and being set "out of square" in their truck frames.

The present standard 80-pound rail of the New York Central and Hudson River Railroad, of which I inclose a cross section (Fig. 17),

*The difference between the two 85 and 90 pound sections is in the angle of sides of head and radii of fillets connecting web and flanges.

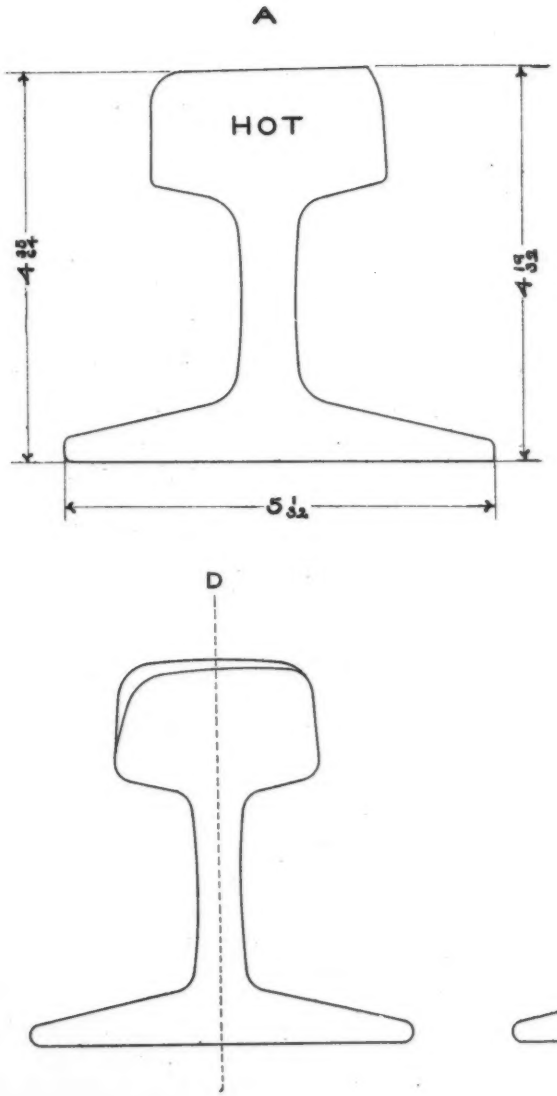

A
HOT
4 23/64
4 19/32
5 1/32
D
E

PLATE LXXIV
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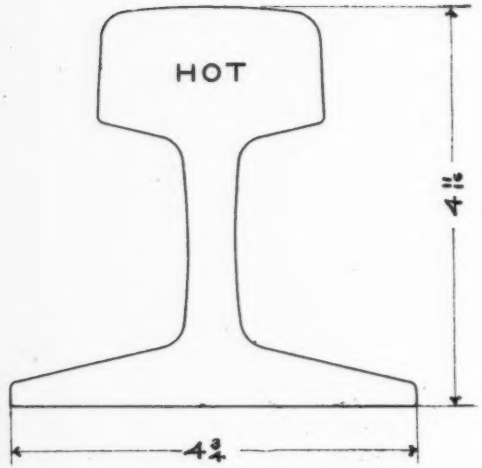
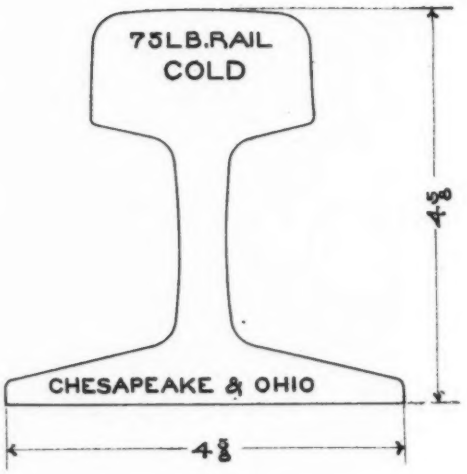
JONES ON
WHEELS AND RAILS.

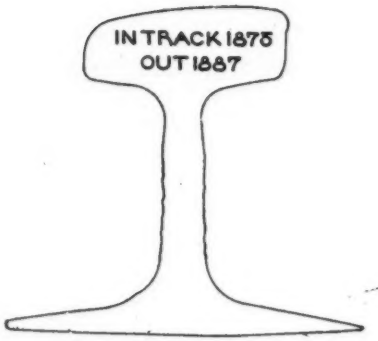
B



C

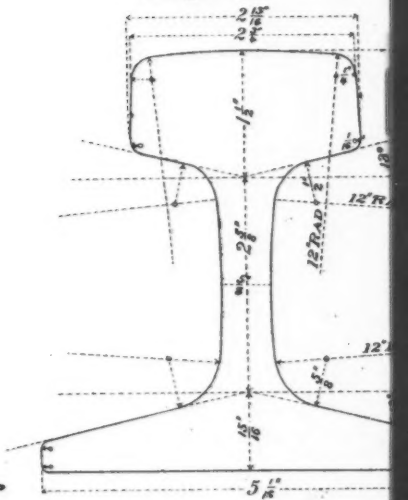


H

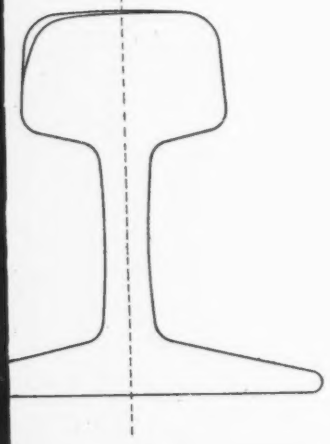


J. No. I 90 LBS.

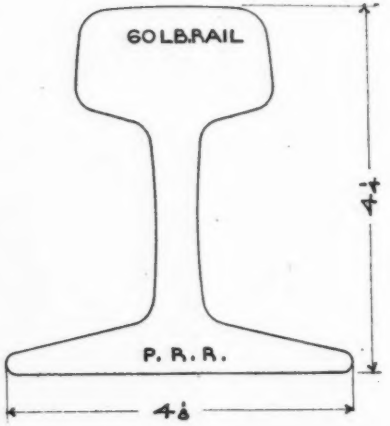
Head 40,56 per cent.
Web 22,61 "
Flange 36,83 "



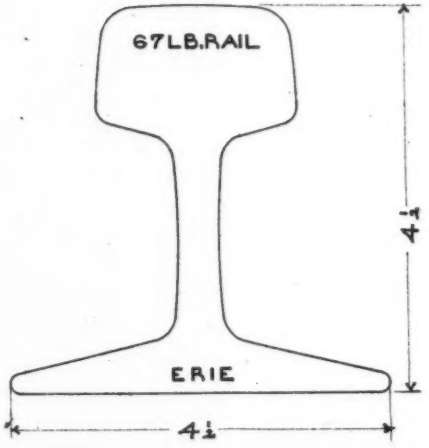
E

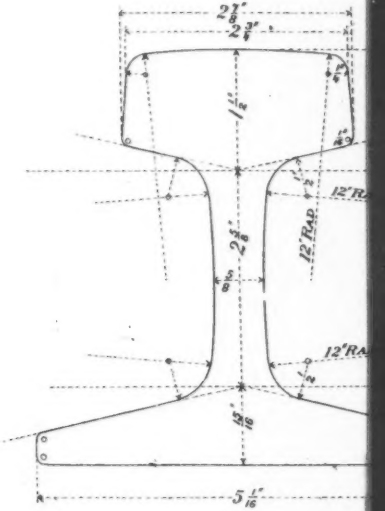


F



G





K No. 2. 90 LBS.

Head 41,35 per cent.
Web 21,82 "
Flange 36,83 "

PLATE LXXIV
TRANS. AM. SOC. CIV. ENG'RS.
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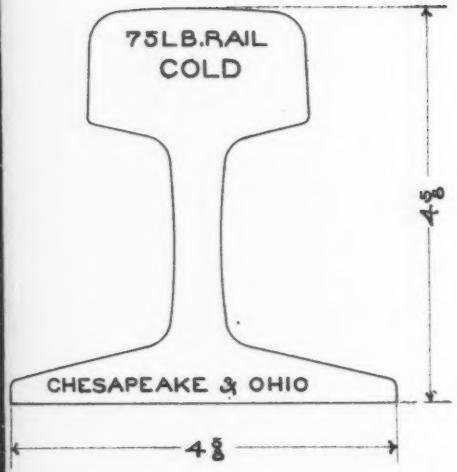
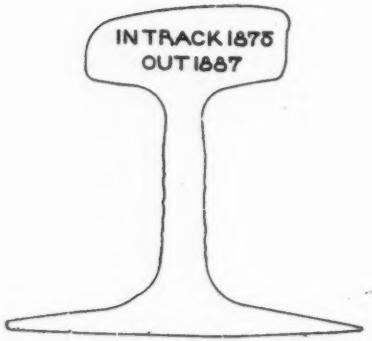
JONES ON
WHEELS AND RAILS.

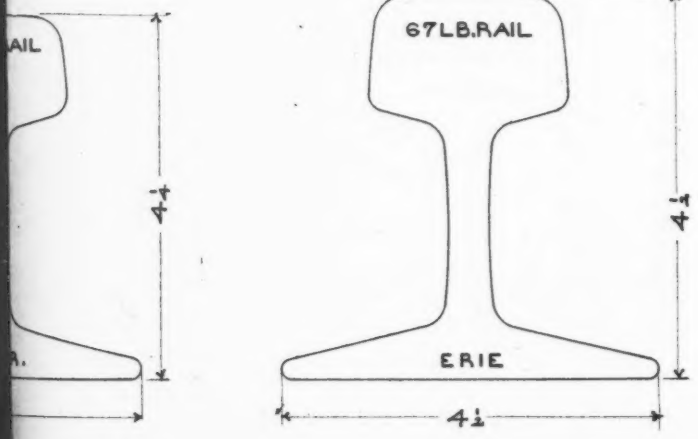
C



H

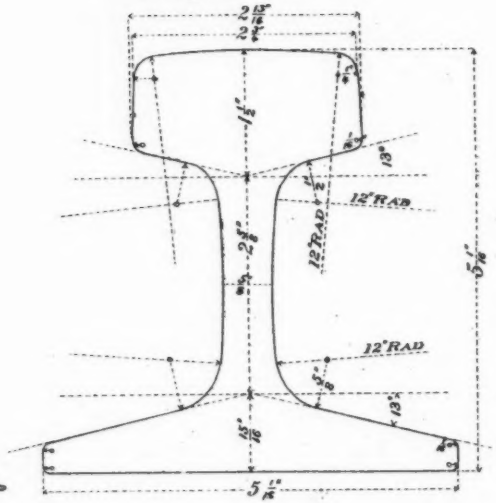


G



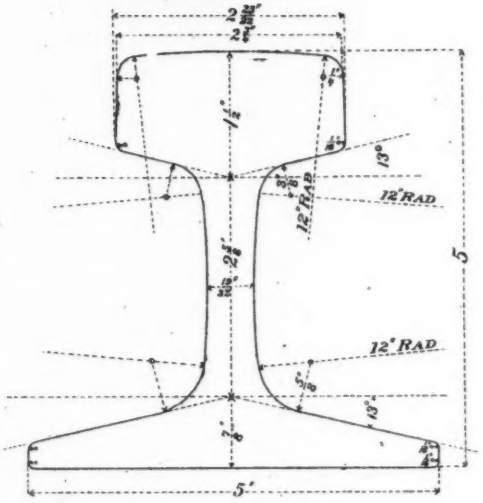
J. No. 1 90 LBS.

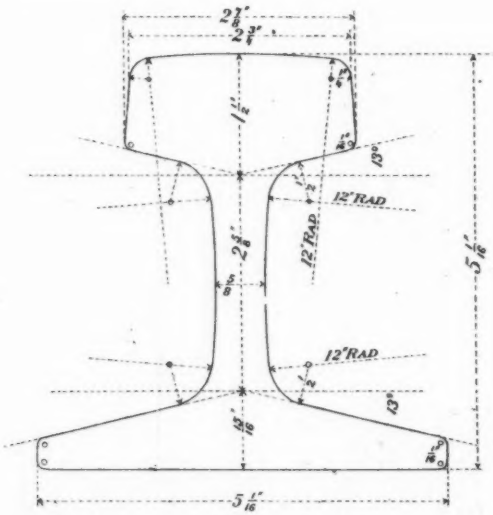
Head 40,56 per cent.
Web 22,61 "
Flange 36,83 "



L. No. 1. 85 LBS.

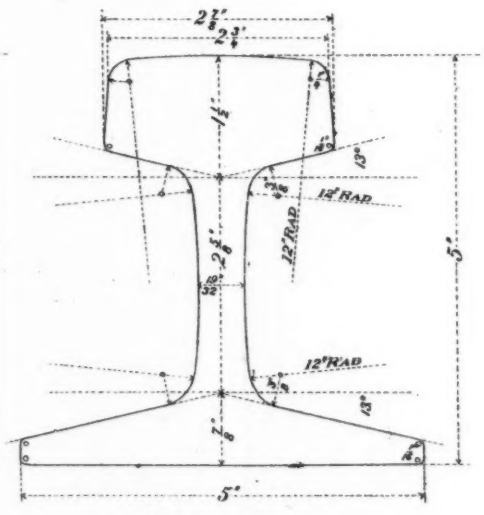
Head 43,08 per cent.
Web 22,56 "
Flange 34,36 "





K No. 2. 90 LBS.

Head 41,35 per cent.
Web 21,82 "
Flange 36,83 "



M No. 2. 85 LBS.

Head 43,72 per cent.
Web 21,92 "
Flange 34,36 "

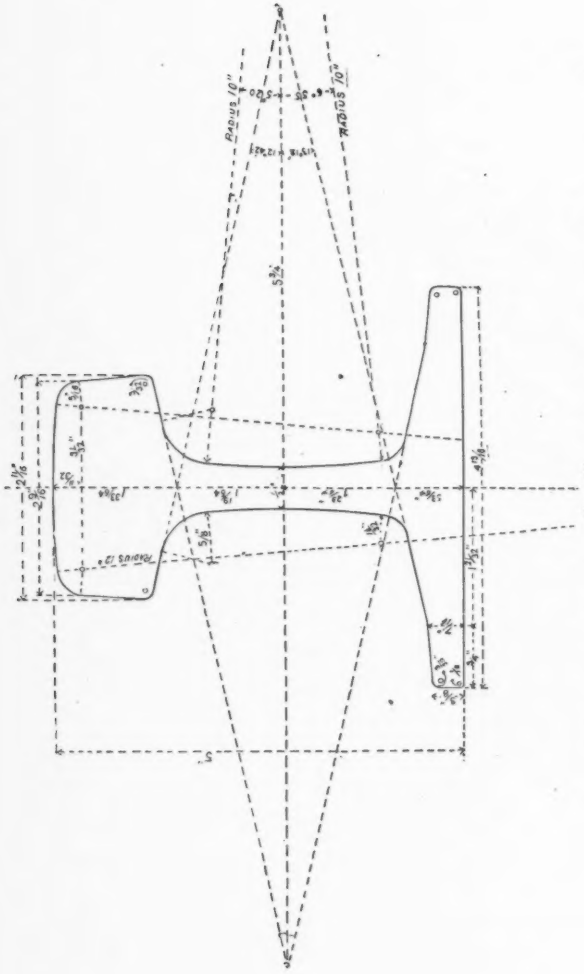


FIG. 17.

New York Central and Hudson River Railroad. Standard 80-pound steel rail, 1888.

has a top width of $2\frac{9}{16}$ inches sides, including outward inclination of $\frac{1}{16}$ inch on each side, makes the width at bottom of head $2\frac{11}{16}$ inches, with a head depth of $1\frac{23}{64}$ inches. This rail is giving very satisfactory results under exceptionally heavy traffic.

I regard the entirely flat top as the theoretically correct form, but necessarily with it must be used cylindrical, not coned wheel treads; but until all coned wheels are withdrawn from the service I think the 12-inch top radius must be maintained.

I do not advise recommending an entirely flat top until all coned wheels have gone out of the service.

I would furthermore add, that for the purpose of obtaining such results as I could from observations upon the rails and wheels of the New York Central and Hudson River Railroad and the West Shore Railroad, I addressed the following list of inquiries to William Buchanan, Esq., Superintendent Motive Power, New York Central and Hudson River Railroad; J. M. Boon, Esq., Superintendent Motive Power, West Shore Railroad; William D. Otis, Esq., General Roadmaster, New York Central and Hudson River Railroad.

First.—What is the percentage of wheels taken out of service for "sharp flange" as compared with removals for all other defects, of all classes of rolling stock, since the adoption of the present standard 65 and 80-pound steel rails?

Second.—What was the same percentage prior to the adoption of these rails?

Third.—Do your observation and records show that the present rail shapes (that is "sharp corners" and nearly flat "tops") are more (or less) productive of "sharp flange" and "hollow tread" in the wheels than the older and more rounded heads?

In reply to which Mr. Buchanan answered as follows:

"In reply to yours of December 12th, will say that the percentage of wheels taken out of service for sharp flanges as compared with the removal for all other defects of all classes of rolling stock since the adoption of our present standard of 65 and 80 pound rail, is 10.56 per cent. and the percentage prior to the adoption of these rails was 13.14 per cent. My observation and records would indicate that the present rail shape 'sharp corners' and nearly flat top is less productive of hollow treads in the wheel than the older and more rounded heads.

"It is my opinion that the shape of the corner of the rail has but little bearing upon the subject. Sharp flanges are seldom found on two wheels that are on the same axle; they are more generally caused by trucks being out of square, 'not true,' also wheels of different diameters being on same axle, as well as curvature of the road."

Mr. Boon answers as follows:

"In answer to your inquiry: the average of wheels removed for sharp flanges is about 20 per cent. of the removals from all causes. In my opinion the throat of the flange should be made to conform to the shape of the head of the rail; or, in other words, the radius of the curve of the corner of rail and throat of flange should be the same. If they

are not, the flange will wear to fit the rail. This wearing will of course be a loss to both rail and wheel. Some years ago I fitted up a lot of wheel chills for a foundry. We had wheels with different radius of throat to rail corner. I made templates and watched result. In every case the wheel was, in a short time, to the radius of the corner of rail head. I believe it makes but little difference in the wear of either wheel or rail whether the corner of the head of rail be large or small radius provided the curve is the same on both. I furthermore believe that the shape of the head of the rail has but little to do with the making sharp flanges. If it had, when one wheel on an axle showed a sharp flange, both wheels should show the same defects. As a matter of fact, they do not. One wheel will be sharp flange and almost invariably the opposite wheel will show a full flange—showing the sharp flange was caused by defect in wheels or truck. When both wheels have sharp flanges, it will be found that they are too wide in the gauge, the flanges wearing sharp from being forced between the rail by the weight on them. We occasionally have a sharp flange on a steel-tired engine truck or car wheel. They will be worn this shape:

the throat of the tire worn to the same curve as corner of rail head. We put this wheel in lathe and turn to this shape: do not turn out the point where the corner of rail head had worn. I have placed wheels treated in this way in front of engine truck on West Shore engines and watched them. In about one year it would be the same as opposite wheel. Now if the rail had worn this sharp flange in the first place, why should it not continue to wear sharp when it had no protection at all, but merely an $\frac{1}{8}$ or $\frac{1}{4}$ inch raise on tire at outside edge of throat? Again, on the sharp curves of the West Shore if the rails wore the flanges, our driving-wheel flanges would wear sharp. In fact they do not. I do not know when I have seen a sharp flange on one of our driving-wheels, and they all come here for turning. Occasionally we see one of the flanges showing signs of wear on one side of engine or one on each side on different axles. We know then that the engine is out of square or the distances between wheel centers is not exactly the same. This is corrected and the wear of flange stops. The trouble we have on West Shore is, the flange becomes heavier and closes up the gauge. Sharp flanges are caused by wheels of unequal diameter on same axle, one wheel wearing faster than the other; trucks being out of square; center pin being out of the center; distance between wheel centers not being the same; side bearings being fast, not permitting truck to curve. The great number of sharp flanges are found on freight equipment, the trucks of which, as a general thing, are too light for the work, of poor design and construction. Locomotive and passenger equipment furnish the least sharp flanges, because the trucks, etc., are of better design and construction."

Mr. Otis replies through his road engineer, Mr. George R. Huse, as follows:

"My own observation, and conversation with different road-masters on the line, give evidence of the superior qualities of the old 'English' rail, but whether due to the quality of rail steel or the form of head I cannot say, but I think much the most is due to the quality of the metal and manner of working. I have been much interested of late in some articles in the *Engineering News* relative to the effect upon the wheel tread and flange of the two styles of rail head. The sharper

cornered and flat-top rail seems to make the best showing so far as wear of wheels is concerned, and plates of both sections of rail worn down correspond very closely in wear, while the flange shows worn sharper with the round head than with the flat." Mr. Otis adds "that he does not think that round heads wear as fast, especially on curves."

These replies I submitted to the review of Mr. Theodore Voorhees, M. Am. Soc. C. E., Assistant General Superintendent New York Central and Hudson River Railroad, which he gives in the following words:

"In reference to inclosed letters, I beg to indorse Mr. Buchanan's statement in full. I do not fully agree with Mr. Boon, inasmuch as I believe we get best results from a rail with a sharp corner in the head, not necessarily the same as the angle of the flange of the wheel. In other words, would prefer the wheel and rail should not exactly fit."

In conclusion, therefore, I would say that the final result I have arrived at in my own mind after a very careful study of all that has been said and written, together with my own observations and experience on this subject, is that the true theoretical form of the "relation of wheels and rails" is that of a cylinder rolling on a plane, which, reduced to practical form to give the best economical results, is the following:

Wheel.—Cylindrical tread.

Fillet radius, not less than $\frac{3}{4}$ inch.

Rail.—Flat top, ultimately, 12 to 14 inches radius for the present.

Top corner radii not to exceed $\frac{1}{4}$ inch.

Width of head as large as it can be made within the limits of perfect rolling, and not deeper than $1\frac{1}{2}$ to $1\frac{5}{8}$ inches for an 80-pound rail.

Stem not less than $\frac{1}{2}$ to $\frac{5}{8}$ of an inch.

Width of base, not less than the height.

Thickness of the edges of the bottom flange not less than $\frac{1}{4}$ inch, and for 80-pound rail $\frac{5}{16}$ or even $\frac{3}{8}$ of an inch is not too much.

Olin H. Landreth, M. Am. Soc. C. E.—Sharp flanges are not eliminated by any form of wheel or rail under discussion.

I do not consider that the statistics presented warrant the conclusion as a general rule "that when the wheel is sound and the quality even, about one-half the wheels get sharp flanges."

I consider "that wheels which fail from flange wear are among the most durable, if not the most durable, approximating if not exceeding the life of those which fail from long continued tread-wear alone," but I do not consider that this fact warrants the further conclusion that "no appreciable money loss results from wheels running to flange instead of failing from tread-wear only, since the money loss incurred is not limited to wheels withdrawn on account of sharp flanges, but includes the following losses: 1st. The loss of the remaining unknown life or mileage of the wheel withdrawn for sharp flange. 2d. The loss due to side rail-wear corresponding to flange-wear. 3d. The loss due to tread-

wear of three wheels of the truck caused by lateral sliding friction due to the tendency to run to flange. 4th. The loss due to lateral top rail-wear corresponding to 3d. 5th. A loss due to motive power expended in producing the wear of items 1st, 2d, 3d and 4th.

While I am not prepared to reject as untrue the fact "that the rate of wheel wear grows very materially greater as the rail corner is rounded off to fit the flange," I still consider that the data and facts presented, as well as my own observation, leave the truth of this proposition unproven. My reasons are—first, I have plotted the values of the tonnage and rate of rail-wear given in Tables Nos. 8 and 9, and they show such large discrepancies between individual results as to attach great uncertainty to the slight tendency observed toward an increase of rate of wear with increased age—*e. g.*, the plotted curve of wear on tangents and on 3-degree curves shows discrepancies so great as entirely to mask any tendency in either curve toward an increase or a decrease of rate of wear with age. The curves of wear for 1-degree and 4-degree curves show tendencies to increase of rate of wear on a portion of each curve and equal tendencies to decrease of rate on equal portions of the curves. The plotted curve of wear for 5-degrees curvature shows a tendency to a decrease of rate of wear with age, and the curve for 6 degrees shows a tendency to increase of rate. Second—Even if the slight tendency to increase where shown could be accepted as conclusive, this could easily be accounted for by the wearing through of the hardened skin covering the rail, since its existence is well known, and since there is no tendency to a decrease of wear with age shown by the plotted curve of wear on tangents; this does not therefore disprove the existence or effect of the hardened skin, as is claimed in the last sentence on page 30 of the preliminary report.

I consider that flat-top rails (flat when laid) would be "likely to be effective in reducing rail-wear," but I do not "advise recommending an entirely flat top," because I believe that would be overdoing the proper remedy, and would not insure so low a rate of wear as a rail-top having a radius of curvature greater than 14 inches, but not entirely flat. My reasons are based on the following considerations, which are confined to top rail-wear alone, and exclude side rail-wear as in no way effec[illegible]e special question of top curvature. When a rail has worn to a [illegible]anent form of curvature it has reached a condition of nearest possible approach to a uniform distribution of wheel-load, and hence the lowest maximum wheel-pressure across the rail-top, and therefore has attained its minimum rate of wear. Could a rail have been given at first a curvature which should remain permanent in radius, it would, therefore, insure a minimum rate of wear throughout the life of the rail, Such a curve should be sought, and when determined should be adopted in the manufacture of the rail. A top curve which should remain permanent throughout the life of the rail would doubtless differ from the

permanent curve assumed by a rail that had worn to its permanent form from a curvature originally sharper or flatter, since the form of the original curve would effect the form of the tread-wear of the wheels rolling on it, and this form of tread-wear would in turn effect and determine the form of the ultimate curve assumed by the rail-top. Car wheels rolling over rails ranging in original curvature from 6 to 10 inches top radius ultimately wear all rails on which they run to an average top radius of about 14 inches on tangents and about 10 inches on curves. Were all rails of a system laid originally flat and all car wheels running over them originally cylindrical, it appears impossible to escape the conclusion that the rails would ultimately wear to a curved form and that the permanent curve assumed would be flatter in curvature than if the rails had been laid with the usual 6 to 10-inch radius. The grounds for these conclusions are:

First.—It would be impossible to lay rails or mount wheels or maintain either so truly as to insure a uniform bearing of the cylindrical wheel on the flat-top rail; owing to this, there would result an augmented wheel-pressure and an augmented wear toward either one edge of the rail or the other, or both edges successively, according to the condition and rigidity of the rail fastenings, and a curved form of the rail-top would result.

Second.—Even were this impossible uniformity of wheel pressure across the rail attainable, the different portions of the rail-top are not equally strong against wear under heavy compression; the portions near the edges having less metal outside them would be deformed under lighter pressures than the central portions, and the same effect, namely, a curved rail-top, would be the result.

Third.—The curve thus produced would gradually become sharper until a permanent form should be reached, which, however, would be flatter than if the rail had been laid with the usual curvature of 6 to 10 inches radius, since the wheels starting originally with straight cylindrical treads, and being worn more by the outer portions of the rail-top than by the inner, would remain straight across the tread, or, if worn curved, would assume a flatter curve than if the rails had been laid with the usual sharp top curve; hence the permanent curve assumed by the rail—which is dependent on the curve of the wheel-tread—would also be flatter than the permanent curve which the rail would have assumed had it been laid with the usual sharp curve—*i. e.*, the permanent curve would be flatter than 14 inches on tangents or 10 inches on curves. The exact value of this radius it is impossible to determine in the absence of experience with flat-top rails, but it is hardly probable that it would be less than 20 inches under ordinary conditions of track, or 30 inches where unusual precision in track-laying or great rigidity of rail-fastenings should exist. If now a rail of 6 to 10 inches original radius wears flatter and assumes a permanent curve of about 14 inches radius, and a flat-top

rail wears sharper and assumes a permanent curve of from 20 to 30 inches, say 25-inch radius, it follows that the curve sought, viz., one that would wear neither flatter nor sharper, should have an original curve radius of betwe 14 and 25 inches; the precise value of this "radius of no variation," le falling between the above limits, could be precisely determined only by experience. I am strongly inclined to the opinion that rails laid with such a top curve—*i. e.*, one of about 20 inches radius—would result in a lower rate of top rail-wear than either of our present forms or Mr. Whittemore's proposed flat-top rails, and would give equally low rates of side rail-wear.

Mr. Sandberg objects to the flat-top rail from the "producers' point of view," for the following two reasons:

1st. The heads of flat-top rails would be more porous than curve top, because the flat top necessitates less pressure or work in the last roll-groove, and hence less closer grained than the curved top.

2d. The heads of flat-top rails would not deliver so well from the rolls, and more "wasters" would be the result.

The first objection appears to me to touch the true root of the evil of undue rail-wear, viz., a lack of density and hardness in the heads, but should not be directed against flat-top rails alone and made a ground for their rejection, for the difference of density of rail head due alone to the form of curve of rail top must be quite insignificant since it is measured by the versed sine of one-half of the top curve, which in the flat-top rail would be zero, and in Mr. Sandberg's rail of 6 inches radius, $\frac{1}{12}$ of an inch. In either form the density is mainly given—as in the perfectly flat base of the rail—by the pressure or work of the rolls acting upon the semi-fluid metal and forcing it against the vertical surfaces of the rail-grooves, which act simply as moulds to shape the rail base and head. As the rail metal at its passage through the last grooves is far from being perfectly fluid, the final pressure on the rail-head and rail-base is far from being equal to that produced by the rolls on the web and sides of the head. This remarkable fact, that the portion of the rail on which the least pressure and work is expended is the very portion on which the heaviest and most severe service falls, points to the desirability of considering if modifications or additions to our present mode of rolling rails may not be possible.

The second objection, concerning the difficulty of delivering flat-top rails from the rolls, is doubtless a valid one, but one which would be obviated by giving the rail any appreciable curvature which should release the horizontal grip on any one portion of the rail head as soon as that portion should have passed the point of contact with the rolls, or, as Mr. Sandberg says, "as long as the rail is not flat;" hence a 20-inch radius would not be subject to this objection.

A. P. Man, Jr., M. Am. Soc. C. E.—I think this matter of shape of head has not been discussed (except corner) sufficiently in this article to decide

as between wide or deep head. It is entirely a question as to where the metal is needed for wear. According to this discussion seven-eighths of all rails are not on outside of curves. Is it wise to put the metal on as if all were on the outside of curves? Such may, however, be deemed the weak point to be protected, perhaps. I incline to favor the deep head rather than the broad, even if a fish-plate only be used at joints on inside of rail and a heavily reinforced angle plate to match on the outside. Is there any important objection to such an arrangement?

HUNTER MCDONALD, M. Am. Soc. C. E.—The tendency of all well mounted and matched wheels is to hollow treads, which, of course, have a curved surface on account of lateral play; a flat-top rail will not reduce this tendency.

When treads are worn slightly hollow the bearing will be on the corners of the flat-top rail alternately, seldom on both corners at the same time on account of greater width of concave surface of wheel than head of rail.

The crushing force of load will be more disastrous to the rail if applied to unsupported corners than to the supported middle of rail.

The curved-top rail will practically afford greater bearing surface than the flat-top.

Most of the defects in sections, illustrated in Mr. Whittemore's paper, are defects of construction and not directly the result of curved-top rails alone.

The tendency of flat-top rails will practically be to increase the corner radii.

Cylindrical wheels will soon wear hollow, and most wheels now in use are already more or less hollow.

Unless the change were made simultaneously on all systems, Mr. Whittemore's desired result could not be reached, because the flat-top rail would hollow the tread of cylindrical wheels, and the already hollow treads would round the corners and top of the rail.

MANSFIELD MERRIMAN, M. Am. Soc. C. E.—As I have cast my vote in the final report of the Committee on Wheels and Rails in opposition to the flat-topped rail proposed by Mr. Whittemore, it may be well to give a reason for the faith that is in me, which is based not only upon the facts set forth by that committee, but on the fundamental laws of sliding friction. It is now, of course, well known that the old laws of friction, as stated by Morin, are but rude approximations, and it is well established by experiments made during the past twenty years that the co-efficient of sliding friction varies not only with the velocity but also with the intensity of the normal pressure. When the pressure per square inch is high, the co-efficient of friction, and hence the total resisting force of friction, is less than when the pressure per square inch is

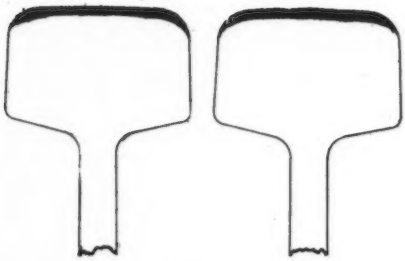


Fig. 1.

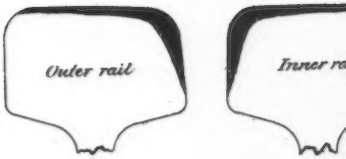


Fig. 4.

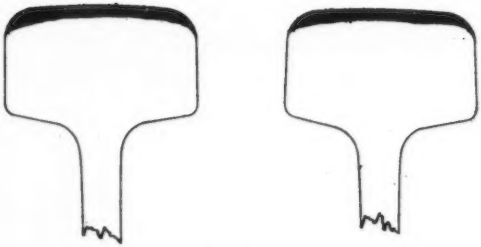


Fig. 2.

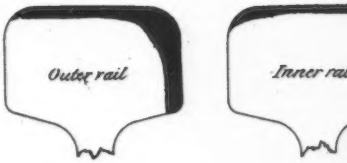


Fig. 5.

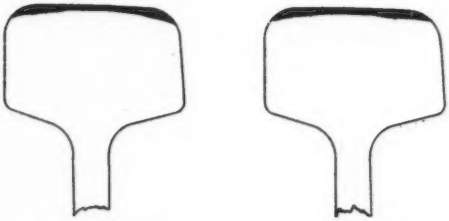
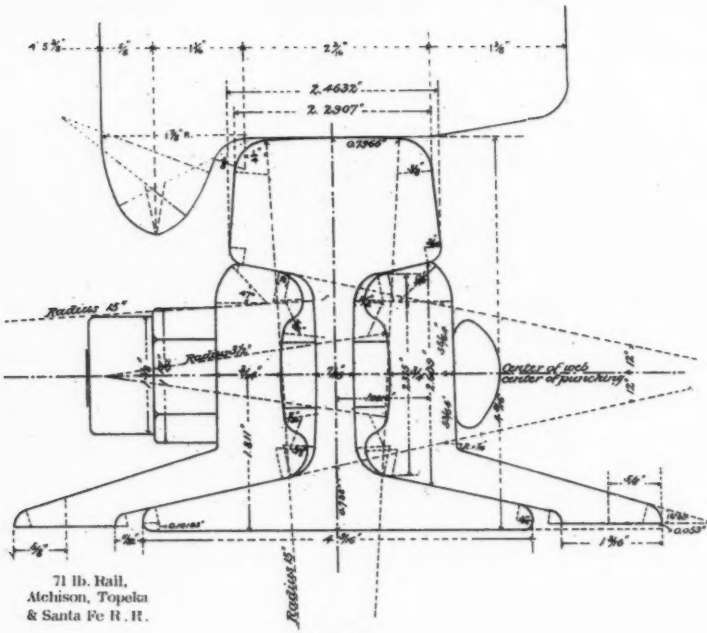


Fig. 3.

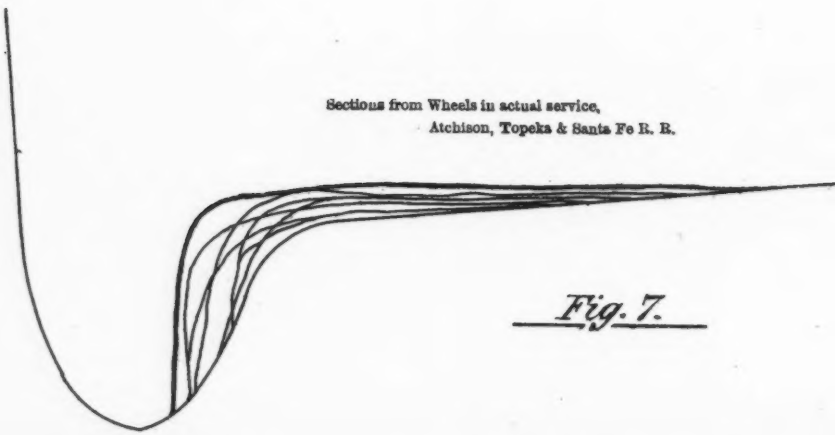
Fig. 6.

Sections of Worn Rails, Atchison, Topeka & Santa Fe R. R.



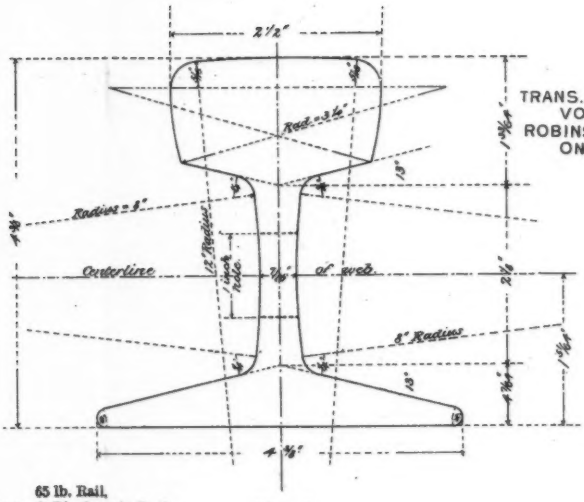
71 lb. Rail,
Atchison, Topeka
& Santa Fe R.R.

Fig. 8.



Sections from Wheels in actual service,
Atchison, Topeka & Santa Fe R. R.

Fig. 7.



65 lb. Rail,
Denver & Rio Grande R. R.

Fig. 9.

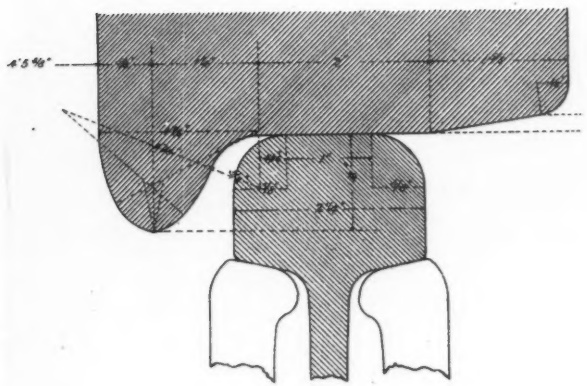


Fig. 10.

low. The application of this principle to the contact between wheel and rail seems to indicate that the top of the rail should not be flat, since on account of the difference between the wheel gauge and the track gauge there is a lateral sliding of from ½ to ¾ of an inch. Previous discussions have pointed out the fact that probably this lateral sliding is one of the main causes of the wear of the rail. Now, if the line of contact across the rail is large, say 2 or 2¼ inches, the pressure per square inch is less than if that line of contact is 1½ or 1 inches, so that in the former case the co-efficient of friction is the greater, and hence the wear of the rail is greater, as also is the amount of fuel required to pull the train. If this sliding friction were the only thing to be considered I should advocate a small radius for the top of the rail, but as the wear due to pounding and crushing is also large, we are between two fires, and must select a mean radius which is not small and also not very large. It appears to me that, considering all the elements of the question, the committee's proposition for a 12-inch radius is as fair a mean as we can arrive at under our present knowledge of the subject.

James A. Millholland, General Manager George's Creek and Cumberland Railroad.—I fully agree with the committee that, as the bearing surface on the top of the head of the rail is narrowed by a rounding off of the upper corner of the head, the wear upon the head grows very materially. My position, however, is that as the corner is rounded to fit the wheel fillet, from a former sharpness, the wear upon that corner does not grow as rapidly, as it approaches a fitting with the wheel fillet, as it did when it was relatively sharper.

S. Fisher Morris, M. Am. Soc. C. E.—I see no objection to the Michigan Central rail, but would modify it by making the top entirely flat, which is the form I recommend. I think that a flat top will reduce rail wear and give longer life to both rails and wheels.

John Newell, M. Am. Soc. C. E.—My views on the subject of rail sections are expressed in the accompanying sections for 65 and 70 pound rails, Plate LXXV, the latter the heaviest weight used upon our line, the Lake Shore and Michigan Southern.

An inspection of these will give my views better than I can in the limited time I have to devote to the subject.

Ernest Pontzen, Cor. M. Am. Soc. C. E.—The tendency to sharp flanges is a consequence of the rigid connection of the axles of the truck or car. The wear of flanges increases with the distance apart of the rigid axles; it will diminish when the tread of the wheels is coned and the top of rails curved. If the rails are soft, the sharpening of flanges will progress less quickly.

If the rail corner and the side face of the head fits the fillet of the flange, the wear of rail and of wheel will be great, as there will be friction on all points of contact which are not situated on the rolling line.

If the shape and material of the wheel treads and the distance between the axles were altered, it is probable that the radii observed on worn rails would not be the same as those named (12 inches and ½ inches).

It is most important to have the fillet of flange well chilled; as that can be secured better by a large fillet radius, I would admit a ¾-inch fillet radius.

I would admit the 12-inch radius or even a flatter top, but only if the tread of the wheels is cylindrical. In case of conical tread I would reduce the radius of the top to about 9 inches. In the first case the flatter top reduces the chances of producing grooves in the tread; in the second case, the shorter radius seems to me to be suitable for maintaining the wheels in proper position without the aid of the flanges, and it also prevents more effectually the squeezing out of metal on top of the rail. Such deformation of the top of rail results at once in a reduction of duration of rails and of wheels, as the metal thus protruded increases the wear of the fillet of flanges.

Some difficulty will be met in rolling rails with flat top. I would for these reasons give preference to rails with a curved top, the radii being selected in accordance with the shape of the wheel tread (cylindrical or conical).

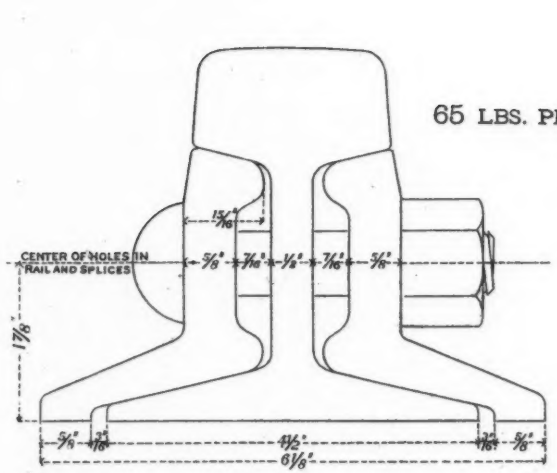
I had wished to furnish some drawings taken from rails used on our railroads, but could not in time for publication in the present discussion.

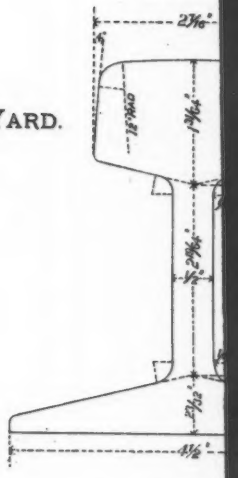
The distances between the axles of our cars (four-wheeler or six-wheeler) are somewhat greater than in American rolling stock, as the greatest number have been built without trucks. I hope that in time the utility of trucks will become more appreciated in Europe.

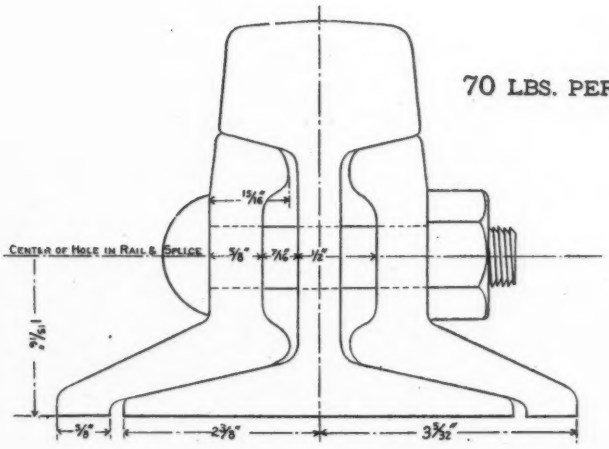
Messrs. Thomas Prosser & Son.—We take pleasure in handing you a circular that we have issued regarding flange and tread of wheels and tires, and believe that if all the roads adopt the Master Mechanics' and Master Car Builders' standard flange and tread for all tires and wheels it would greatly help to reduce sharp flanges and unevenly worn rail-heads.

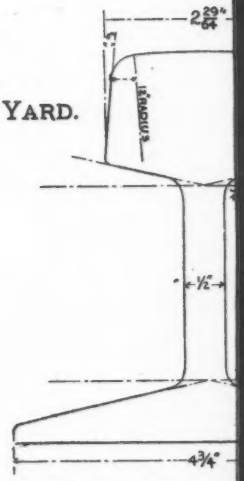
As we understand the matter, it is the desire of your Society to adopt a standard rail-head which shall be suitable for the standard flange and tread adopted by the Master Mechanics' and Master Car Builders' Associations, as we presume that there is no question about many accidents having occurred from the flange and tread not fitting the rail perfectly.

In our circular we state that, unless otherwise requested, we will in future furnish all locomotive driving wheel tires, leading locomotive truck wheels, tender wheels and car wheels, with the flange and tread adopted by these associations, as it seems to be the general disposition



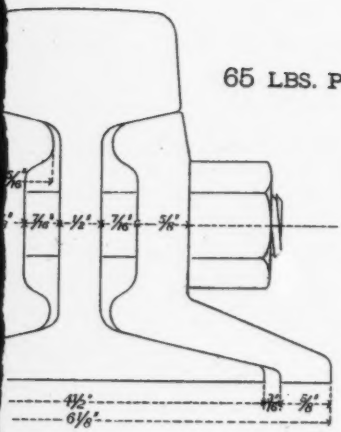






LAKE SHORE & MICHIGAN SOUTHERN RAILROAD.

65 LBS. PER YARD.



70 LBS. PER YARD.

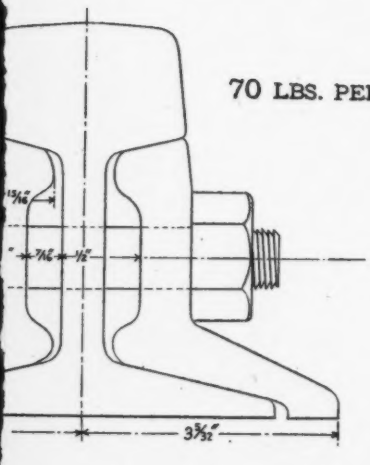
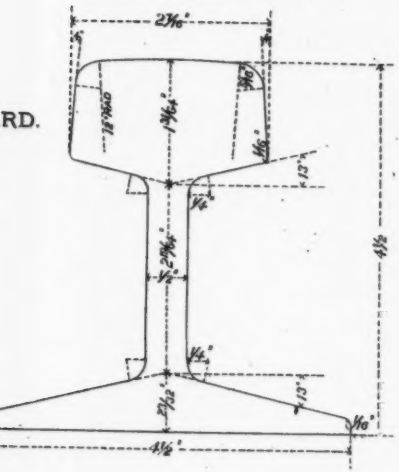


PLATE LXXV
TRANS. AM. SOC. CIV. ENG'RS.
VOL. XXI. Nº 425.
NEWELL ON
WHEELS AND RAILS.

RD.



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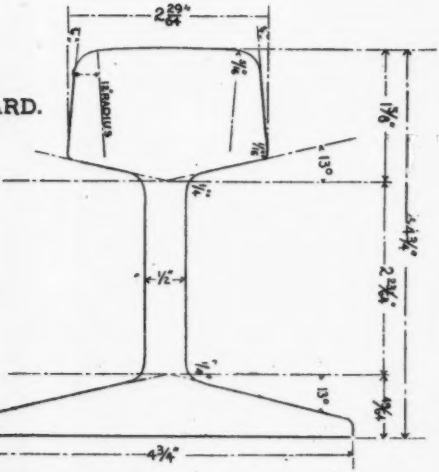

ERN RAILROAD.

of railroad officials to adopt this flange and tread as a standard, and most of the orders we have lately received so specify.

A few months ago we had on file between seventy-five and one hundred different styles of flanges and treads, and are pleased to report that with hardly an exception the parties using them have notified us that they have adopted as a standard the flange and tread adopted by the Master Mechanics' and Master Car Builders' Association, and it is hoped it will be made the "standard" in every sense of the word.

S. W. Robinson, M. Am. Soc. C. E.—From the study of ball bearings, as consulting engineer for the mountings of the Lick telescope, I am certain that Mr. Whittemore is correct in keeping the load within the elastic limit of wheel and rail, and that the top should be very nearly or quite flat for best results in service. Although I think a perfectly flat top cannot be maintained in service, yet I believe we should seek to obtain as nearly that as possible.

A. A. Robinson, H. V. Hinckley and Lewis Kingman, Members Am. Soc. C. E. (by joint letter).—No doubt sharp flanges are a natural and inevitable phenomenon to some extent, but we believe it is well to have the rail and wheel sections correspond as far as practicable at the place where the most wearing is done, and that, as in any machinery, a respectable "fit," supplemented with an avoidance of surplus loose motion, will not increase the wear.

The committee think wear is largely due to trucks being out of square and to unequal diameter of wheels. Tangent rail wear, however, on the Santa Fé (of which Figs. 1, 2 and 3, Plate LXXVI, are samples of sections taken at various points on the system) does not show on the side of the rail-head where we should expect to find some of it if (in connection with the flanges in actual service, Fig. 7) these causes of wear were so prominent.

As to quality of wheels and defects therein having much to do with their wear, there is no doubt.

As to the conclusion of the committee, that no money loss results from wear running more to flange than to tread, we do not fully agree with them. If the head of rail has insufficient height the rapid wear of flanges means the early contact of splices and flanges, and it is not impossible that this contact on curves has been the cause of some of the many "derailments, cause unknown."

With a high-headed rail, flange-wear is also evidently not desirable, for on any rail-head we do not want the flange and splice to touch till all the available wear has been utilized from the crown of the rail. On the Santa Fé, as a matter of safety to passenger traffic, the wheel tires of all passenger equipment and of over 90 per cent. of engines are steel.

This accounts for the nearly vertical flange indicated by heavy line in Fig. 7, Plate LXXVI (which shows sample sections from wheels in actual service on the Santa Fé), and the nearly vertical wear on side of rail heads on the Raton Mountain (Figs. 5 and 6), where maximum grade is 185 feet per mile, and where engine and passenger car wheels are all steel. We call attention to this fact in connection with Figs. 5 and 6, because when splice and flange touch, the rail is no longer fit for service either under passenger traffic or otherwise.

On account of heavy mountain grades the Santa Fé can not go back to cast-iron wheels for passenger service, and with steel prefers that wear shall not be excessive upon flange as a matter of economy to both wheel and rail. As to radius of upper corners of rail the Santa Fé has always used $\frac{3}{8}$ of an inch. We prefer the smallest radius practicable for both wheel and rail.

Fig. 8, Plate LXXVI, shows the Santa Fé 71-pound rail, and its other sections are similar.

Fig. 9 shows the recently adopted 65-pound rail of the Denver and Rio Grande.

The Santa Fé rail has nearer the contour of the flange, and consequently must lose more metal in service before it will lose the same amount of gauge.

On the other hand, the Rio Grande rail has more metal in the top of the head to wear, and is stiffer.

Rails made with heads tapering like those of the Santa Fé may get the same splice-bearing by using vertical sides and $\frac{1}{16}$ radius, or a point for lower corner of section of rail head. This change we are ready to adopt. We want the rail and wheel to have the same radius, and are not in favor of a $\frac{3}{8}$-inch radius for wheel fillet and a $\frac{3}{8}$-inch rail corner to cut into it.

With the wheel section, which we understand to be the present standard, the result would be as shown in Fig. 10. We prefer, however, that the radius of wheel fillet and upper rail corner both be $\frac{3}{8}$ of an inch. Then if vertical sides be advocated we are ready and glad to adopt them.

Whether rail top be flat or not, the tread of a cylindrical wheel will always wear hollow, and the hollow will not fit a flat rail top, but, on account of centrifugal force on curves and the oscillations on any track, will be a curved line substantially as with old style coned wheels. With flat-top rail the bearing of load would be at extreme corner of head instead of on crown.

All Santa Fé rail-heads have about 14 inches radius. With the coning of wheels that have in years past gone over the system, the general shape of the crown has been preserved (see Figs. 1, 2 and 3), and we prefer to retain a radius of either 12 or 14 inches for top of rail, though possibly 10 inches would be best. The radii of worn wheels seem to average about $\frac{3}{8}$ of an inch, varying from $\frac{1}{4}$ to $\frac{3}{8}$ and more.

Considering rails and wheels together (*i. e.*, both of them), the minimum wear appears to be when radii of parts of contact are nearly or quite alike, nor is there any doubt in our minds as to the advisability of making them so at the start.

The wear of the gauge will be less as we approach this relation at the beginning, and will be less after this condition is attained than before; therefore let us have as near this condition as possible at the start.

At all events, we hope we shall not drift back from $\frac{3}{8}$ to $\frac{7}{8}$ of an inch radius for wheel fillet.

If there is, as the committee suggests, "no particular necessity for having any single standard radius for rail or wheel," there certainly does exist a necessity for uniformity in sections and in the gauging of track and rolling stock. Whatever radii be adopted, we want four points settled:

First.—A method of gauging.

Second.—A definite place on the head of rail to which to measure the gauge.

Third.—An allowable variation each way from standard gauge.

Fourth.—An allowable variation between wheel-gauge and track-gauge.

In our opinion the matter of determination and preservation of gauge is one of the most important points in this whole matter.

The rolling stock that passes over the Santa Fé system varies in wheel-gauge at least $1\frac{3}{8}$ inches by actual measurement.

The difference in rail heads allows at least $\frac{1}{2}$ an inch more variation in gauging, and some roads do and some do not widen gauge on curves and at switches, so that the total variation of our "standard" 4 feet $8\frac{1}{2}$ inch gauge (not mentioning 4 feet 9 inch) is more than the width of the rail head and is a constant element of danger, often resulting in spreading or tearing up of track and springing of angles at switches, and the spreading of track on curves, and consequent derailment and wrecks.

Whatever will tend to reduce this variation of gauge to a minimum will have our hearty support, and the first act to that end is the adoption of standard sections and methods of gauging. We object to the extreme slope of sides of rail, as in the Lehigh Valley standard, on account of loss of metal in top of head, where most needed for stiffness and wear.

We object to the Cumberland Valley rail and wheel sections for the same reason, and the additional difficulty of placing split switches without cutting main track rail.

The advantages of a curved rail top are:

1st. Bearing over web of rail.

2d. Better contact of rail with wheel.

3d. Less resultant "flow of metal" on rail corners.

We prefer Fig. 8, either as it stands or with vertical sides and points for lower corners, but are willing to compromise and adopt Fig. 9, or even 10, if by so doing we can secure the general adoption of a standard.

Better that any one of the four sections (Figs. 8, 9 or 10, or 8 with vertical sides) be adopted than to be using all the present varieties in the same service.

C. P. SANDBERG, C. E.—On the whole the rail section shown in Fig. 1 of the report, the adopted standard of the Michigan Central, is in my opinion decidedly the best of the three, and with very slight modification would meet with my entire approval, but not so the two others. I have replied to each question with "yes" or "no," but will now give my reasons for such replies.

One-quarter-inch radius is much too small for any rolling stock not provided with bogies, and absolutely dangerous for derailment with fixed axle journals, as used in Europe. It may do for America with your bogie system on both engines and carriages, but even there it is hard to see what will be the gain by such a small radius, and why not have half an inch, as I have adopted in my standard sections, of which millions of tons have been made during the last thirty years. This reply will also serve for "A," Figs. 2 and 3.

Twelve-inch top radius.—For reasons given in my reply to Mr. Whittemore's paper,* a 12-inch radius gives a less compact head than one of half that. However, as stated before, steel rolls better than iron, anything between 6 and 10 inches would do. Since my reply to this question I have seen the Manager of the Dowlais Iron and Steel Works, Mr. E. P. Martin, who rolled that very flat-topped rail,† and he entirely agreed with my statement, adding "they may perhaps retort upon you that if it is so difficult about making a flat top, how about making a flat bottom?" to which I replied that no one is having a round bottom but himself.

Vertical Sides.—I entirely approve of the same. I have kept them on my standard sections all through from the beginning. In Europe the reverse inclination is used to that in America (see section of Russian and German rails in my last paper "On the use of heavier rails")‡ This partly offers the bulk of the rail head to greater wear, and partly clearance of side friction from the tire flange, but gives a somewhat smaller support to the fish against the rail head; however, the difference is so small that the gain by the lately adopted sections Nos. 2 and 3, is hardly worth while mentioning, compared with the disadvantage of the above-mentioned main points. Besides the side friction, which in No. 3

* Transactions, Vol. XXI, p. 166, October, 1889.

† See Plate LXIV, Transactions, Vol. XXI, p. 168, October, 1889.

‡ Proceedings Institution of Civil Engineers, Vol. XCV.

must be enormous, the gauge may alter by the wearing of the rails, and it cannot but be regretted that such a large quantity of rails have been made to this section in America.

The very small lower corner, $\frac{1}{8}$ to $\frac{3}{32}$ of an inch.—I approve of this entirely, as giving more bearing to the fish, and taking advantage of the metal, steel, being rolled to a sharper corner without the slightest difficulty. In fact I find the sharp corners give less wasters or cracks than the rounded, just the reverse to what it used to be in iron, and why should we then not take advantage of the new metal, steel, when it is an advantage to both producer and consumer?

A most important measure is missing on all the three drawings, namely, the width of bearing surface between the rail head and fish, and in practice it is absolutely necessary that the fish-plate touching surface of the rail should be as straight as a line, not rounded as it is inclined to be with the usual mode of rolling, this being all the more important when using the three tie fishes of 44 inches in length, as they would be no good unless a perfect fit to the rail be effected from the commencement, and as the straightening of such a long fish affords considerable difficulty, this may be one reason for its slow adoption.

The very broad head.—I entirely approve of it for two reasons: first, that the broad head would be more compact than a narrow thin one; secondly, that it would offer more wearing surface to both rail and tire, and give increased traction power for the same weight of engine. For this reason my "Goliath" rail is designed $2\frac{5}{8}$ inches, and the Belgian Goliath is $2\frac{7}{8}$ inches, and I do not see the reason why it should not go up to three inches, or, approaching the wearing surface of the tire, say $3\frac{1}{4}$ inches, all for heavier rails where the substance or depth of rail at the edge would not be less than $1\frac{1}{4}$ inch, so as to allow at least $\frac{1}{2}$ an inch wearing surface from the top.

Another important question missed on the three drawings is the thickness of flange, this measure being entirely left out. In this respect Fig. 1 seems to be the best, Fig. 2 entirely condemnable owing to the thinness of the flange, which would necessitate rolling the steel of such softness as to endure but little wear, which is now sadly proved in America, and from which a wrong conclusion is often drawn, viz.: that it is the fault of the big head, that actually gives no more wear than the small head. I have devoted two pages (14 and 15) in my paper to this important subject.

R. I. Sloan, M. Am. Soc. C. E.—I inclose herewith a section of rail, Fig. 18, which was taken up after about four years use on the Manhattan Elevated Railway, at the Coenties Slip curve, in New York City. The lines of the top of the rail show that it had worn nearly flat. In my opinion, formed from my observation on this road, it does not make much difference whether the top of the rail is flat or slightly curved; the wheels wear the surface down to accommodate themselves.

FIG. 18.

63-pound rail used on the Manhattan Railway at Coenties Slip, showing section October 12th, 1883, when laid, and section September 5th, 1887, when taken up. Radius of curve 125 feet (outside rail).

The following is a statement of the traffic over this rail:

Third avenue traffic from October 12th, 1883, to September 5th, 1887:—1 423 days, 501 trains, 2 048 cars per twenty-four hours.

Second avenue commenced running April 12th, 1885. Traffic from April 12th, 1885, to September 5th, 1887:—876 days, 395 trains, 1 523 cars per twenty-four hours.

	Cars.	Engines.
Third avenue	2 914 304	712 923
Second "	1 334 148	346 020
	4 248 452	1 058 943

	Tons.
Average weight of cars, 14 tons	59 478 328
" " engines, 17 "	18 002 031
Total	77 480 359

A. J. SWIFT, M. Am. Soc. C. E.—States that he does not advise recommending an entirely flat-top rail, because he thinks coning desirable to steady cars, and that coned wheels do certainly bring about curved tops on rails.

Also that any deductions made from wear caused by wheels of varying gauge and template cannot be a safe guide for the future, when $\frac{1}{8}$ of an inch fillet will probably be universal and a uniform gauge may be expected and hoped for.

G. H. THOMSON, M. Am. Soc. C. E.—I do not consider that the evidence submitted is sufficient to warrant the assumption that "the tendency to sharp flange is a natural phenomenon, which must exist in all perfectly running wheels," for the reason that the tendency is not inherent in the wheels themselves but is from the slewing of the trucks, causing them to run "out of square," and this is due to the short wheel base. If the distance between the wheels of an ordinary freight car truck were reduced say to 38 inches, the phenomenon of "sharp flange" would be more frequent, for the reason that the flanges of the wheels would then impact the rails at an angle more favorable toward the production of "sharp flanges." If the angle of impact be improved by increasing the distance between the wheels, the number of sharp flanges would decrease. Minor causes, such as mis-mated wheels, soft chilling, etc., localize the sharp flange and determine the life and wear, in a measure, of the wheel.

The Dudley section laid in 1884 upon the New York Central is, although soft (.32 carbon), as a rule attesting the mechanical wisdom of a 12-inch top radius, and in the first year of its use double flanges on driving wheels were the rule rather than the exception. Its radius after five years' use is still 12 inches.

I object to the wide and thin flange of the Michigan Central section, (the thickness of the rail base is not given, but is understood to be $\frac{5}{16}$ of an inch, and the section rolled .45 to .50 carbon).

I would prefer the $\frac{1}{4}$ inch radius under the head increased to $\frac{1}{2}$ or $\frac{5}{8}$ of an inch.

I object to the vertical sides of the head.

The above objections hold for this section at 80 pounds and at .45 carbon.

A comparison of the Michigan Central section with P. H. Dudley's section of the same weight, designed in 1883, is herewith presented. It does not appear that the Michigan Central section is as stiff as the Dudley section; nor can it be rolled harder or at a better finishing heat, and after wear and oxidation the latter section would still be the stiffer one.

COMPARISON OF RAIL SECTIONS.

	80-pound Dudley, 1883. Square inches.	80-pound Michigan Central, 1889. Square inches.	Difference. Square inches.
Head area	3.44	3.29	— 0.15
Neck "	1.60	1.72	+ 0.12
Base "	2.73	2.86	+ 0.13

	Dudley. Per cent.	Michigan Central. Per cent.	Difference Per cent.
Head area	44.2	41.8	— 2.4
Neck "	20.6	21.8	+ 1.2
Base "	35.2	36.4	+ 1.2
	100.00	100.00	

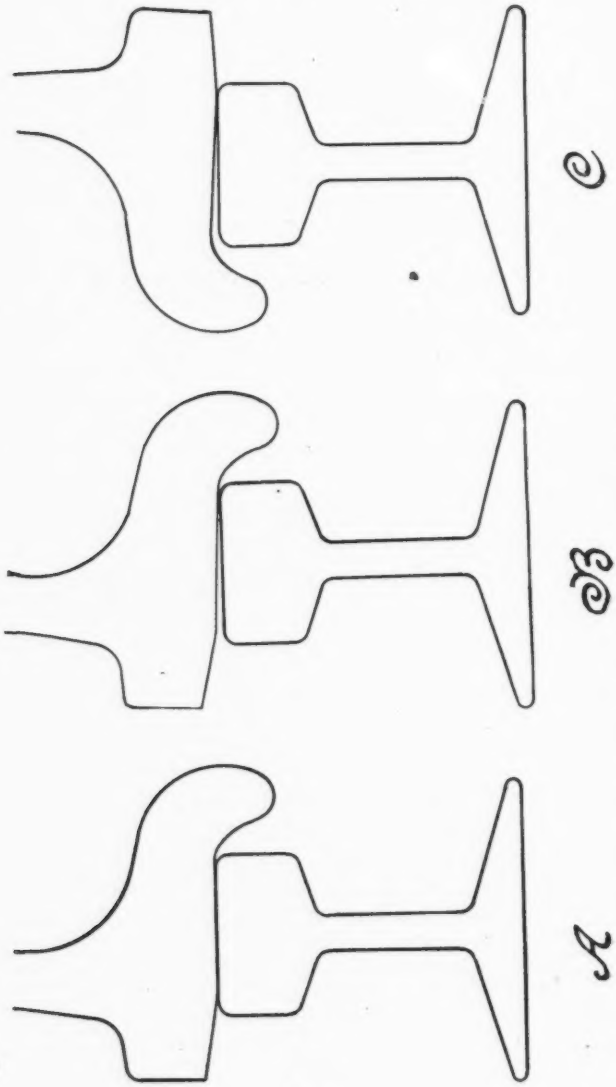

FIG 19.

	Inches.	Inches.	Inches.
Head top radius	12	12	0.0
" corner radius	$\frac{5}{16}$	$\frac{1}{4}$	$-\frac{1}{16}$
" lower "	$\frac{3}{32}$	$\frac{3}{32}$	0.0
" depth	$1\frac{23}{64}$	$1\frac{1}{2}$	$-\frac{1}{64}$
" top width	$2\frac{9}{16}$	$2\frac{1}{2}$	$-\frac{1}{16}$
" bottom width	$2\frac{11}{16}$	$2\frac{3}{4}$	$-\frac{3}{16}$
Height	5	5	0.0
Neck thickness	$\frac{1}{2}$	$\frac{9}{16}$	$+\frac{1}{16}$
" top radius	$\frac{5}{8}$	$\frac{1}{4}$	$-\frac{1}{8}$
" bottom radius	$\frac{1}{32}$	$\frac{1}{4}$	$-\frac{3}{32}$
Base width	$4\frac{13}{16}$	5	$+\frac{3}{16}$
Base thickness, least	$\frac{3}{8}$	$\frac{5}{16}$	$-\frac{1}{16}$

I do not think that at the present time the absolutely flat-top rail will reduce rail wear, especially on trunk lines, interchanging with foreign roads, with all kinds of wheels, "double flange," etc.

I think there are objections to the absolutely flat-top rail. In a straight axle with the wheels and the flat-top rail recommended by Mr. Whittemore in his invaluable paper, that coincidence of face line of wheels and top of rail sought (shown at "*A*" on Fig. 19) obtains only when both rails are absolutely level, or lying within the same plane, but this perfection of track surface is unknown; lower one rail $\frac{1}{8}$ of an inch, and the concentrated bearing (shown on Fig. 19 at "*B*" and "*C*") results, with probable consequent crushing rather than wearing of the rails.

Also on curves, the "rocking" of the outside rails, even if level, or inclined in the same plane, would tend to shift the bearing toward the corner of rail. It seems to me that the cylindrical wheel and rail of very broad head and of large radius (say 20 inches or more) would be the best economy, but only when an absolutely uniform track surface can be cheaply maintained. This cannot be done now with T-sections and angle joints, but if some new sections permitting a broad head be devised, and if the joints can be got rid of, the problem is solved, and the art of railroading will experience a most decided advance in rail economy. With top radius large and rails slightly out of surface as referred to each other, the tread line of cylindrical wheels will be tangential to some part of the rail top, and therefore the wheels will be always in relatively wide bearing.

I do not at present advise recommending an entirely flat top under the conditions the flat-top rail would be subject to on most railroads.

In conclusion, I will add that too much in the way of protest cannot be said against the use of 60 000 capacity coal cars as referable to rail endurance and economy.

W. Howard White, M. Am. Soc. C. E.—By counting up the rail sections on pags 38 and 39 (pp. 244 and 245, *ante*), of the preliminary report of the committee, which show a corner radius of 0.26 or under, I find fif-

teen out of thirty-two in this category, and it therefore does not seem to me proven that the head generally wears to about ¼ of an inch radius.

The head radius seems to be very various. It will average 12 inches, perhaps.

Have never made any extended measurements which would throw light on this point, but think that where much side wear takes place the corner generally wears to a greater radius than ¼ of an inch.

I approve the rail section shown (Michigan Central) in all respects, except the vertical sides, and disapprove these because they do not allow as much bearing for the splice as would be available were they inclined.

I disapprove the splice shown as having too much metal in the lower flange and web, with the consequent result of depressing the vertical axis and leading to excessive fiber elongation in the upper side of splice when reacting from load and to consequent rupture. I much prefer the Sayre type of splice as remedying this defect and that of the insufficient bearing for rail head.

I inclose a form of rail section, Fig. 20, which appears to me the best answer I can give to the last circular of the committee, which, however, I answer also categorically.

From my observation the faults of our rail section and joints are as follows:

First.—Too little bearing for the wide treads of the wheels, and consequent grooving or double flanging of wheels and rapid wear of rails.

Second.—Too little bearing for the splice bars on the head of the rail.

Third.—Too narrow a bearing on the tie, and consequent rapid cutting down of the latter.

Fourth.—Too great a bottom flange of the splice bars, leading to a low position of the neutral axis of the bar and to a great separation of the neutral axis of the rail and splice bar.

The result of the latter is injurious to the splice, by diminishing its efficiency through its unsymmetrical form.

The effect of the want of coincidence of the neutral axes of rail and splice is somewhat difficult to predicate, but the difference of proportional elongation of the top and bottom members of each under similar stresses cannot but be unfavorable to the member which is always weaker, viz., the splice.

The section I present, it will be observed, is made up of the Michigan Central and Lehigh Valley splices by adopting what I consider the good features of each.

I retain the broad, flat and shallow head of the former while flaring its sides to get bearing, and thinning the base and adding ¼ of an inch to its width.

I think the records will show that few, if any, steel rails have failed from being too shallow in the head or too thin in the base, though some of these rails have been worn down in use far below the point at which the surface of the head becomes too uneven for good riding.

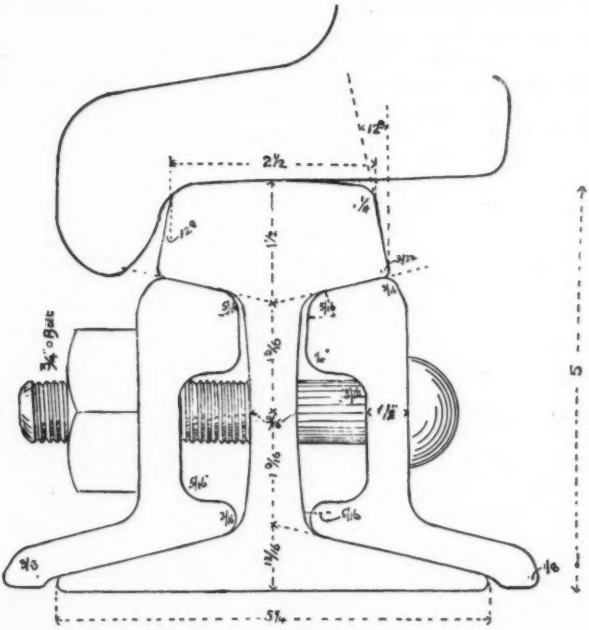

FIG. 20.

My increase of base width is smaller than is desirable, and than will be found, in my opinion, practicable, but it is a gain of 5 per cent. in resistance to the cutting, without resort to a bearing plate. The latter will, I believe, be found in use open to the objections of noisiness, which is so unpleasant in the chair rail when the greatest care is not taken to keep the fastenings tight.

An incidental advantage of a flaring head is that the width of metal to be worn off increases with the wear, which will have a tendency to check unequal wear of the top.

D. J. WHITTEMORE, Past President, Am. Soc. C. E.—I have presented my views on this general subject in a paper, and in replies to discussions upon that paper; I will only add that I utterly fail to see any reason, theoretical or mechanical, for having a curved top to rail beyond

what is necessary to provide for corner curves, where the wear must necessarily be unequal through the oscillation of wheel on rails by difference of gauge of wheels and track. Beyond these corner curves the rail should be of such width as to permit a bearing subject to practicable uniform pressures, and this bearing, I contend, should be straight and not curved, and that such a bearing is entirely practicable whenever rails and wheels are properly constructed.

I shall be prepared to believe that there should be no anxious effort to increase the contact between wheels and rail whenever it can be proven that the sharp edge of a razor can be drawn across one's throat with the same immunity against injury as its back, and not before.